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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

MARCH, 1927

THE CONTRIBUTION OF SCIENCE TO THE WELFARE OF THE NATION[1]

INTRODUCTION BY THE CHAIRMAN

By Dr. JOHN M. COULTER

BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH

One of the most outstanding features of the sesqui-centennial period we are celebrating is the progress of science. In fact, during that period, it has revolutionized our civilization as to its methods and opportunities, as well as advancing our knowledge of the wonderful processes of nature. It is very fitting, therefore, to recognize this fact by arranging this symposium.

In the advance of science, it has become differentiated into so many separate fields of activity that it is impossible to include them all in a single program. We are beginning to realize, however, that what we call "science" is a great synthesis, all phases working together to produce the results. Formerly we worked in separate compartments, but now the partitions have been broken down, and our work is becoming more and more interlocking. In other words, science is becoming more like the work of an army than of independent scouts. There must be scouts, but the army follows.

[1] Program prepared for a meeting under the auspices of the American Association for the Advancement of Science to celebrate the one hundred and fiftieth anniversary of the signing of the Declaration of Independence at the Sesqui-Centennial Exposition, Philadelphia.

Speaking very briefly of my own subject, botany, I wish to call attention to its progress and to the great public service it can render. During the early part of our sesqui-centennial period, the only study of plants was their classification, really a cataloguing of our plant material. Now we find it is essential for the discovery of plants available for use, for food, for manufactures, for sources of important drugs, oils, resins and other materials. In other words, it is the kind of work that discovers our natural resources, like the discovery of valuable mines.

The second phase of botany which developed was the study of plant structure, to its minutest detail. We now find that knowledge of plant structure is needed by many industries, as illustrated during the great war, when it was applied to the production of explosives and to the timber used in aeroplanes. This is a good illustration of the interlocking of pure science and applied science.

Later, botanists began the investigation of how plants live and work. It was really the application of physics and chemistry to plants. We discovered what plants get from the air and soil. It will be appreciated at once that such

knowledge is fundamental in effective crop production. This work has certainly been an important factor in the revolution of our agriculture.

The next phase of botanical work was the study of plants in relation to their environment. What were called plant communities began to be recognized, which means that plants do not grow at random, but are associated in definite community groups. These groups were found to be the best indicators of soil conditions, and the practical application was to use these plant communities as crop indicators, that is, as indicating the kind of crop that would bring the largest return under these conditions. In fact, no phase of botanical progress has been without its important practical application.

Growing out of the previous phases of work, attention was drawn to the problem of forestry, an increasingly important problem as population increases and demands upon forests begin to exceed the supply. The problem was how to secure a perennial forest crop rather than to destroy this essential crop.

Next it began to be discovered that with all our developed knowledge of the value of plants and the effective method of their production, they were frequently attacked by destructive diseases, which neutralized all the other efforts. To meet this situation plant pathology began its career, and the result has been not only success in checking the ravages of disease, but in many cases the discovery and development of disease-resistant races of important crop plants.

Finally, the study of inheritance began to develop and has grown in a remarkable way. It began as very pure science, with no suggestion as to any practical service, but now it is being applied to the improvement of old crop plants, the securing of new crop plants, the development of drought resistant races, and the development of disease resistant races.

This bare outline of the progress and service of botany illustrates the situation in all the sciences. There is one fact, however, that we should always emphasize. This progress has not been due to the study of practice, for the study of practice alone is sterile. It has been due to the fundamental research which has advanced our knowledge, and incidentally this knowledge has suggested new practice. In other words, our increasing service, through better practice, is only a by-product of fundamental research. Even our present knowledge is relatively superficial, and the deeper we delve into research, the wider is the superficial application of our results. The fact is that men engaged in fundamental research are stimulated by knowledge for its own sake, and not by its possible usefulness. Knowledge, however, is essential to service, so that our progress in science, which may be likened to the exploration of an unknown continent, opens up new fields for cultivation. The spirit of the explorer leads him continually into new territory, and as he opens it up he leaves it to the practical farmer to cultivate.

There are three conspicuous tendencies in botanical research to-day, which will help us to forecast the future of research.

(1) The first tendency is to attack problems that underlie some important practice. This tendency was stimulated by the great war, for at that time botany was called upon to solve many important practical problems. This tendency is so strong at present that I do not believe it will ever subside, but it should be understood. There is no evidence that it is tending to diminish research whose whole purpose is exploration of the unknown; but our recent experience has shown us that many important practices suggest fundamental problems of pure research.

(2) The second tendency is an increasing realization of the fact that bo-

tanical problems are very complex, and must be attacked from several points of view. For example, in former days, in plant morphology we described structures, with no knowledge of their functions. Plant physiologists, on the other hand, described functions, with no adequate knowledge of the structures involved. Ecologists often described responses, with no adequate knowledge of either structure or function. This is all changing, and around each bit of investigation there is developing a perspective of other points of view and other methods of attack.

(3) A third tendency, which seems to me to be the most significant one, is the growing recognition of the fact that structures are not fixed to their last detail. Once, in morphology, in recording the facts of the development of an embryo from an egg, every cell-division was recorded, and also the plane of every division. It is becoming evident now that many of the recorded details were not significant, and we are having to distinguish those that are relatively fixed from those that are variables.

In conclusion, speaking for science as a whole, its present ideals may be summarized as follows: (1) to understand nature, that the boundary of human knowledge may be extended, and man may live in an ever-widening perspective; (2) to apply this knowledge to the service of man, that his life may be fuller of opportunity; and (3) to use the method of science in training man, so that he may solve his problems and not be their victim.

THE CONTRIBUTION OF BIOLOGY AND ITS APPLICATIONS

By Professor C. E. McCLUNG

UNIVERSITY OF PENNSYLVANIA

This is an age when all things are questioned. It is not inappropriate, therefore, for us to pause as we celebrate 150 years of our country's history to inquire what contributions science has made to progress during this time. One hundred and fifty years—what is such a period projected against the earth's history? How small a space of time, indeed, compared to the millennia of human existence! If extent only were a measure of value, surely we would have slight occasion to consider the years 1776–1926. But other criteria are more compelling, and, we believe, more valuable. Not actual but comparative time seems a better basis of judgment. To the biologist the measure of success in living is the accuracy with which organisms fit themselves into their environment. How thoroughly have they taken conditions and turned them to their advantage? In lower forms of life this means only survival. To man it signifies not only taking advantage of things as they are, but of shaping and directing these and creating new conditions and circumstances for his welfare.

The value of any period of time, therefore, finds its best measure in the degree of progress made in the control over natural conditions. For lower organisms adaptations are of infinite variety, but it is noted clearly that as complexity increases and we come to so-called higher forms, brain power is the measure of successful relations to environment. Because man possesses this in such an outstanding degree he has come, despite relative physical weakness, to a large command over all other creatures. Likewise, he has acquired some measure of

control over the physical conditions of existence. As between various groups of men, here, also, the mark of successful competition is in the exhibition of intelligence. When, eventually, destructive competition between races and individuals is replaced by a competition which includes cooperation, directed towards success in the common conquest of material existence, then an understanding of natural conditions and of human capacity and its utilization for the advancement of a comprehended cosmic plan will proceed with accelerated speed. The past 150 years have more than equalled the centuries before in such development—another such period at the present rate might reduce even the "wonderful century" to insignificance by comparison.

What, after all, is the measure of success in living? Is is personal well-being and happiness; is it merely being good and refraining from evil; or does it consist in some positive, constructive action? Even now it is considered necessary to render some form of service in order to be really successful, and this idea has been found not only worthy, but even immediately profitable. To most people, however, this idea of service is of some action which will benefit those about us. It is largely of the present and not of the future. Almost alone among constructive thinkers the scientist plans in terms of cosmic development. To him the past is of interest only as it is significant for the future. The world of to-day is not a static sphere upon which he prepares for an uncertain personal future, but rather a possibly comprehensible field of action upon which he plays a real constructive part. Always this part has been visioned more or less dimly by the world's great men, but only in these days, as a knowledge of the universe deepens and its infinite scope is revealed more clearly, does it begin to appear in what manner we are involved. And although in these 150 years we have traveled further than in all the millennia before in the comprehension of the realities of existence, as yet not much more than the method of progress has been revealed. Not by looking within, but by searching without, does revelation come. The scientific method, so old and yet so new, is the key which opens the doors of understanding. To us these doors now seem many, but the key is one, and the conviction grows that the final door that marks the convergence of all the paths which now pass through the portals marked "Physics," "Chemistry" and "Biology," and perhaps through others that we know not of, or do not now recognize, is leading to the final portal of "Science." Though the door to infinity be visioned as one, it, also, bears now many names. Those who seek by other keys than the scientific method to unloose the barriers to understanding do not see the name of science above the final goal. But the aspect of the thing matters not if we but regard the proper reality. My old friend, the good Kansas poet, Carruth, well phrases the matter in the poem "Each in his own tongue":

A fire-mist and a planet, a crystal and a cell,
A jelly-fish and a saurian, and caves where cave men dwell,
And a sense of law and beauty, and a face turned from the clod,
Some call it Evolution, and others call it God.

Without, therefore, making odious comparisons, but only in the interests of clear thinking and purposeful action, we must realize that what we see depends upon the direction in which we look and that the picture is colored by the glass through which we regard it. The beetling cliffs, the pounding waves, the scudding clouds, arouse the emotions of the artist and he pictures on the canvas his feelings regarding the eternal conflict between the inertia of the solid rock and the constant attrition of the flowing, streaming water. The scientist

looks upon the same scene and his imagination reaches out also and he visions the means by which it has taken form and, in the light of this revelation, he looks into the future and tells us what will happen as the years pass. There is no conflict between the visions of the artist and of the scientist. They are reflections of the same realities from two types of mind; from one a "sense of beauty," from the other a "sense of law."

If we would order our lives wisely, therefore, we must take thought of these differences and use each contribution in its place. To-day, accordingly, we will inquire, What is the character of the service to the common good rendered by the scientist? Here the poet has supplied the answer in the phrase "a sense of law." This it seems to me is the outstanding contribution of science. In place of chance, we see the earth in the light of laws which permit not only an understanding of what has gone before, but also enable us to vision the future. These laws we feel, not only in our common relations with environment, but we see them holding everywhere. There is always a sense of the inevitableness of a given effect from the same cause. The astronomer, looking through the telescope at distant worlds, finds the same chemical elements producing the same effects upon the physical instruments with which he measures chemical action. In all this scheme of reasonable law, man finds himself as the only creature capable of apprecitaing it and taking part in it. As his knowledge increases, more and more it becomes possible for him to exercise control (at present largely only in matters of detail) but with the establishment of more comprehensive and far-reaching laws, control will become greater. As an instance of this it has been stated that an understanding of the method by which atomic energy operates would make available the command of energies so great that even disruption of the entire earth would be possible.

One outstanding lesson in our progress so far is that the scientific method provides the best means for determining conditions of existence and of providing the means for meeting them. To the final end of such understanding all divisions of science contribute, and it is not well to emphasize the service of one above the others. To-day one makes the chief contributions; to-morrow another. Each supports and contributes to the rest. Therefore, when I speak of the contributions of biology I do so not in an invidious way but merely to indicate how that portion of the general subject of science contributes to the common achievement.

It is desired in this symposium to indicate in what manner the applications of biology have been of value to the nation since its establishment. If I might very briefly indicate some of the valuable applications I would select three as the most outstanding. I believe it may be truly said that, consequent upon the results obtained from biological study, we live a longer life, a fuller life and a more purposeful one.

It may be well to examine a little bit in detail the basis for this opinion. According to the best information that statisticians can give us, the average expectation of life has been raised since 1855 from fifty to fifty-eight years, and, although the figures are not so exact for the preceding period, there was an increase of approximately five years from 1789–1855. This does not mean that the capacity for living has been increased, but only that the conditions have been made so much more favorable that at birth the average expectation has been to this degree increased. Compared, for instance, with the expectation of life in some of the less favored countries, the information is that these fifty-eight years lying before the average American in British India would be reduced to

22.6 years. In addition to what has been accomplished it is definitely stated by competent authority that if we should take advantage of present knowledge and make rigid application of it, the average expectation could be increased ten years. Here we have a clear demonstration of the fact that biological knowledge has made a longer life possible.

The results so far obtained do not indicate, in any large degree at least, a change in the character of the human material, but only in the possibility for its development—there yet remains the probability of actually changing its quality. It has been found feasible in the study of lower organisms, even with present knowledge, by genetical means to alter the inherent character of living material so that it actually exhibits a longer individual life. What has been done with these lower forms certainly can be accomplished with man when knowledge is increased, and, in particular, when a definite purpose lies before us. It was formerly the case that during the first year of life more than half of the children born would die. Quite aside from the human element involved there is here, of course, a tremendous material loss. It is more and more apparent that the individual has a social value and that a system of society which does not include an evaluation of this and fails to adapt its processes to the conservation of individual life is lacking in a fundamental attribute of success. At present social organization proceeds blindly without any appreciation of the value of the individual human life or of conditions which make it of the greatest group value. It would seem quite obvious that, with a given number of individuals living half again as long a time, their contribution to the social structure would be correspondingly increased. We may reasonably expect, then, that one of the contributions of biology will be a real prolongation of the individual human life as well as the improvement of the prospects of its continuance.

When we speak of the individual living a fuller life, the meaning would depend upon the point of view. I think, however, it may reasonably be said that by reducing natural phenomena to operations under given laws there has been removed much of the handicap which prevailed during periods when superstition largely took the place of understanding. At the present time the individual may proceed about his daily tasks quite undeterred by thoughts of vindictive demons or other taboos. There is a certainty about the conditions under which we live because we are largely freed from fears and inhibitions which come from ignorance. Perhaps one of the most outstanding evidences of this is the better understanding of the causes of disease. In former times when plagues swept over the world, often removing half of the population, there was no understanding of the cause of the visitation. Even in the most highly developed of intellectual states, that of Greece, at the time of the great plague, superstition and fear dictated all thought and action. When it became known that microscopic organisms, having definite life cycles and susceptible of attack, are the causes of disease, at once one of the outstanding uncertainties of life was largely minimized. It is true that we have much to learn even in this field, but the principles are known and the methods are at hand by which this greater understanding may be reached, and it is only a question of time, and that probably a very brief one, when most of the common infectious diseases will be banished from the world. From the earliest times a fear of disease and death has been one of the severest handicaps to purposeful action. In savage states the individual born into the world with a physical handicap is almost hopelessly started in life. With even our present improved methods of treating deformi-

ties and injuries, the person who is only physically disabled may look forward to a worthy and helpful life. Especially is this true in the case of children, where in many cases what would formerly have been a hopeless deformity is only an unpleasant incident in their lives.

Civilized countries now rarely face the prospect of severe famine. A knowledge of the plant and animal life has made possible the control of food conditions to such a degree that only very exceptionally does it become necessary to consider the prospect of food scarcity. Not only are the amounts of foods greatly increased through better methods of culture, but the qualities of these have been much improved. Also by proper genetical practice, entirely new forms of food products have been originated. From these and many other circumstances I think it may be truly said that biology has made a fuller life possible by the removal of both mental and physical handicaps.

But how shall we say that biology by its contributions has made a more purposeful life possible? Of all scientists, the biologist is most constantly confronted by the evidences of purpose in nature. No structure that he may find in plant or animal has significance except in terms of purpose. Upon the examination of a new structure, the first question that the biologist asks of himself is, What is the purpose of this? and only by answering this question can he come to an understanding of the presence of the unfamiliar structural condition. It is often held as a reproach to biology that its philosophy is so definitely teleological. But the facts must be faced, and the facts are that living things are explainable only in terms of purpose. If the structural conditions shown in all organisms are constant evidences of purpose, then most certainly their existence, and the existence of all organisms, is an evidence of larger purpose. It is unthinkable to the biologist that any living thing can exist and carry on its functions and depart from the earth without some definite accomplishment, and since in their individual structure and behavior the evidences of purpose are so manifest, then it can not be otherwise than that their presence is a part of a larger purpose which as yet remains without understanding. I should be inclined to say, therefore, that however valuable the contribution of biology has been to material existence, the demonstration which is so universally apparent in all its subdivisions, of an underlying plan, forms the basis for a philosophy of existence which has a very definite and demonstrable foundation. It is not a question of what one feels should be the circumstances of existence, but rather the demonstration of what these circumstances actually are. If the biologist is correct, each individual finds himself, therefore, with the basis for belief that his presence is a part of a large and even cosmic plan, in which, with sufficient knowledge, he can play a very much greater part than is now possible.

Through very extensive studies of living things, something over a half a century ago Darwin was able to place, with some degree of success, the age-long theory of evolution upon a basis of observed facts. The central feature of the evolutionary theory is that organisms are plastic in their nature and are constantly undergoing change. By observing the results of these operations it is noted that there has been formed a graded scale in degree of complexity from the very simplest to the most complicated forms. Paralleling this present complexity is a historical perspective which shows the simpler forms in the earlier periods of the earth's history and the more complicated at the present time. There have been millions and millions of these different kinds of organisms, many of which have completely disappeared. There are only two ways of accounting for this diversity; one is

that there prevails a continuous series, grading one part into the other progressively; the other is that each of these multitudinous kinds has been especially created as such and remains without change. There are no two opinions amongst biologists as between these possibilities.

An almost convincing demonstration of the evolutionary principle has entirely altered the philosophy of the whole world, whether appreciated by the individual or not. The whole texture of scientific thought is permeated by this conception of the relation of elements in the time series. It is by far the most hopeful philosophy that could be conceived, because always there is the possibility of change, and the history of the past has shown that this change is slowly but progressively towards greater perfection and beauty. If biology has rendered no other service to society than the establishment of such a philosophy of hope for development in the future, it would have served well.

SCIENCE, THE DECLARATION, DEMOCRACY

By Dr. J. McKEEN CATTELL

FORMERLY PROFESSOR OF PSYCHOLOGY IN THE UNIVERSITY OF PENNSYLVANIA AND COLUMBIA UNIVERSITY

JEFFERSON and Franklin were men of science as well as leaders of a revolution. Five of the fifty-six signers of the Declaration were physicians; one was a surveyor or engineer, as was Washington; others had scientific interests. More significant for the relations of science to the progress of democracy is the circumstance that our revolution, followed by the French revolution, was synchronous with the industrial revolution, which was caused by the applications of science. In legendary lore little James Watt may have watched the steam escaping from the teakettle on the same day that little George Washington cut down the cherry-tree. However that may be, Watt patented his steam engine in 1769 and it was first put to use by pumping the coal mines of Cornwall about 1776. We can celebrate here equally the anniversary of the political revolution that separated us from England and of the industrial revolution that began in that country. If we look about us at the buildings and exhibits of this exposition and then try to picture what happens in Harrisburg, Washington and Geneva, we can compare the extent to which each revolution has accomplished its objects.

The industrial revolution, beginning with the exploitation by machinery of the coal and iron of England, has not only given us our material civilization, it has also laid the foundations on which social and political democracy can be built. When the feudal system yielded to the industrial system, the wealth created by the applications of science made democracy feasible. Social aristocracy survives in England, but that nation has on the whole led in the development of political democracy, as it has in the manufacturing and in the worldwide trade that are the children of science. The mother of parliaments has had a labor-socialist government; the British flag has followed the commerce on which the sun never sets. Germany by the applications of science to industry became a rival of England with results temporarily disastrous to the world. The United States has now outdistanced them both, with a future that lies on the knees of the gods. History is controlled by economics, economics by the applications of science.

It is often said that science is not concerned with matters such as democracy, liberty and the pursuit of happiness, that all it can do is to supply knowledge as likely to be misused as to be applied for our welfare. But a psychologist, who by profession is concerned with the study of human behavior, has been asked to take part in this program. He does not hesitate to claim that science has been the creator of the modern world, a force more potent than any religion, than any system of laws, than any form of government. The advance of science is not dependent for its results on these, whereas religious, social and political institutions are on the one side based on the truths determined by science, on the other side on the economic conditions caused by the applications of science.

Men have died for their country, right or wrong; for their religion, true or false. The martyrs of science have been comparatively few, but it is science that has led the way to true freedom of thought. The patriot and the saint are partisans. Our poet may say:

> Truth forever on the scaffold
> Wrong forever on the throne.

But the balance is pretty evenly weighted. Those with the power, whether in state or church, have ever been ready to impose their creeds and their control upon others.

Far be it from a psychologist to claim that men of science are not also partisans. But we are such as men and not as students of science. He is no longer a scientific man who tries to force others to accept the discoveries that he makes, the laws that he finds, otherwise than by stating them and by using them. Know ye the truth and the truth shall make you free. If it is asked how the scientific man knows the truth, the answer is that he does not. He makes approximations and the bank of his knowledge is solvent so long as it honors his drafts. The Euclid-Newton bank honored until recently all the drafts that were drawn on it. It appears that it may fail to do so for some little ones; if this proves to be the case then our physical universe must be revised or discarded. It is equally true that no social system, no political theory, no religious creed, can be maintained when it is not in accord with science. The methods of science, slowly gaining in force and volume through the centuries, will in the end bring truth and reason into all our beliefs and actions. At least that is the hope of the world, for we can not rely on inherited instincts to meet situations always increasing in complexity.

There can be no conflict between science and religion, between science and nationality; neither are they separate spheres that do not touch. Metaphysics and theology, religion and art, declarations and constitutions, may be true or false, beautiful or ugly, useful or harmful; these are all facts open to investigation, however ignorant we may be at the present time in regard to them. For me there are no more beautiful words than "In the beginning God created the heavens and the earth." Whether the story of the first chapter of Genesis is a true account of what happened six thousand years ago is a question of fact. It is absurd to try to reconcile religion and science when there can be no conflict. The bison had the prior possession of the prairies, but it is futile to try to reconcile the right of one of them to stand on the railway track with the right of the locomotive engine to run over the track. A debate between Dayton and Darwin is appropriate only to the rural vaudeville stage.

There are doubtless influential scientists who would not agree with these remarks. Some of them have recently joined with clergymen and publicists in a manifesto reconciling religion and science with the help of the ambiguous use of words. One of them claims that

if psychologists do not find evidence for the soul, it will be saved by a paleontologist and two physicists. We all agree, however, that while we may dispute concerning matters of which we are ignorant, we shall accept the verdict of science when it is rendered. William James may be correct when he claims that we have the right to believe any hypothesis that is sufficiently alive to tempt our will, for he makes the essential reservation. Once he said to me when discussing the optimistic and pessimistic views of the world: Some people may see a checker-board as white with black spaces, others as black with white spaces; why should we not side with those who see it white? The obvious answer was: Why not see it half white and half black?

The Declaration of Independence begins with the statement that it is a self-evident truth "that all men are created equal." This appears to be more comforting than Calvin's conflicting claim that some infants are born to be damned. But no statement in the Declaration, whatever the reverence in which we may hold it, and no dogma of a church, however great its historic authority, can be maintained, if it is contrary to the results of scientific investigation. The first psychological measurements of individual differences were made by me. We now know that men differ not only in size of body, but also in what with equal opportunities each can do. New meanings may be read into the words of declarations and creeds, but that is not the way to respect them. It is far better, as does the scientific man with his superseded theories, to honor them as the dead bodies over which we have advanced.

There are no self-evident truths; all men are born unequal. Democracy should not claim that all men are equally fit to do anything; it is more nearly a system by which all can attain the positions for which their native inequalities fit them, without help or hindrance from privileges of birth and property. As a matter of fact the Declaration is not particularly concerned with defining or forwarding democracy. It is a Declaration of Independence rehearsing the "repeated injuries and usurpations" of the king of Great Britain and maintaining the right of revolution to redress these wrongs. There is nothing in it incompatible with setting up a hereditary monarchy of our own; Jefferson and Washington were fit to be the founders of a landed aristocracy.

The Constitution, like the Declaration, was not written in the interests of democracy. It adopts a system of checks and balances adverse to popular government; its provisions making amendment difficult, indeed its very existence, are undemocratic. It is a fine defense of individual liberty and some of us may wish that its spirit were still a living force. There is a certain absurdity in adding the eighteenth amendment to the early articles maintaining the freedom of speech and of the press, the right to keep and bear arms, the limitation of searches and seizures, and the right to trial by jury. Legislation such as the recent sedition laws is subversive of the principles on which the nation was founded. Modern social democracy must, however, limit individual freedom for the general benefit. The complex civilization created by the applications of science requires controls that would have been intolerable for the colonists of the eighteenth century.

True democracy has become feasible only since the Declaration was signed one hundred and fifty years ago. When the *Nineteenth Century* magazine asked various notables what were the chief advances of that century, democracy and science were most frequently referred to, these two being named by individuals so diverse in their interests as Gladstone and Jenny Lind. But probably neither

of them realized that the applications of science are the prerequisite of democracy.

We still await greater production of wealth through the applications of science and its more equitable distribution for the further advance of democracy. England has at present a partial political democracy and a rather complete social aristocracy. Russia has more nearly a social democracy and a political oligarchy. We live under a limited social and political cleptocracy. The word may be a bit harsh, but we should learn to subsume under the eighth commandment the securing of political office and legislation by money or favors, and the obtaining of more money than services are worth by inheritance, privilege, monopolies, tariffs and the like. It is fortunate that science provides so much real wealth, even though it may not yet have taught us how to distribute and use it properly. We may hope that the superstructure of paper wealth, which gives the few the control of the many, may in the end be rebuilt by science for the housing of democracy.

Wealth is not an ultimate good, but a means to other ends. It is an essential means to democracy in the modern world. A kind of democracy is more or less feasible in a primitive tribe, though it is doubtful whether it has ever existed, there having been always a patriarchy or other hierarchical organization. When, however, needs are simple and nature provides for the necessities of a small group, there can be a kind of equality without excessive labor and apart from the applications of science. But in fact science begins with the first tools and the most primitive industries; the advance of civilization has been entirely dependent on the accumulation of knowledge and its wider applications.

The earliest civilizations, Egypt, Babylon and the rest, were made possible by the beginnings of science, but in that stage of development human slavery was necessary. One of the Egyptian pyramids is comparable in size and cost to an office building in New York City. The pyramid required the labor of thousands of slaves working for many years. They toiled as many hours a day as they could be kept standing by the lash; their women and children worked in equal measure. The pyramid served as the tomb of a king. The modern office building may be built by a comparatively small number of men working eight hours a day for a few months. Each man is paid what would have provided for the subsistence of a hundred Egyptian slaves. His children must go to school and can go to college. The office building may be used by ten thousand people.

The great civilizations of Greece and Rome were based on slavery. Athens had perhaps thirty thousand citizens and three hundred thousand slaves; it drew on subject nations, and the city, as always, was parasitic on the country. Rome conquered the world. In distant Palestine Christ said: "Render unto Caesar the things that are Caesar's," but just why the hard-earned pennies of the Jewish peasants were Caesar's is not clear. There is no word against slavery in either the Old or the New Testament. A civilization based on the control of the many by the few and the support of the few by the many could endure only by force. The barbarians from the north, the rustics, the submerged classes, overthrew it, and there were larger groups having opportunity and the chance to rule.

There gradually emerged civilizations in Italy, Spain, France, Germany and England. Chaucer and Dante were born. Guilds were established. The universities of Bologna, Paris and Oxford arose. Roger Bacon was born at the time King John was forced by the English barons to sign the Magna Charta. Constitutional government and

trial by jury were established. Greater democratic control parallelled the advances of science. Copernicus was nineteen years of age when Columbus reached America. New heavens and a new earth were then created. Science and democracy advanced together until the time of the industrial revolution and of our revolution when there was an inflection point on the rising curves of each. But always it was science that led in more correct knowledge of the world, in providing wealth that supported larger numbers of free and educated people.

Lincoln and Darwin were born on the same day; the slaves of the south were emancipated and the Origin of Species was published at nearly the same time. Legal slavery will never again exist; freedom of thought will never again be openly suppressed. Our task now is to do away with the subordination of the individual and the limitation of his freedom by economic, social and political controls. We must get sufficient wealth and so distribute it that every child will have opportunity to do what he can do best; that every one will have the chance to read, talk, think and live.

It does not follow that because science provides the nearest approximation to the truth for the time being attainable that people will accept it, or that if they do it will apply to their behavior. As the Latin orator said long ago, we see the better things but follow the worse. Neither do we have general education, leisure and democracy because the wealth provided by science makes them possible. Our material civilization has been created within five hundred years; man has scarcely altered in ten thousand years. In so far as there has been a change it is probably in the direction of a weaker muscular system less well coordinated, defective senses, greater susceptibility to disease, less adequate responses to simple and fundamental situations, including the more elemental emotions and the finer forms of art.

Material science has done its part by giving us more knowledge of the physical and biological world and by supplying those applications which make it unnecessary that there should be slavery, the exploitation of races, the subjection of women, child labor, excessive manual toil. Birth rates and death rates have been reduced to one half; the length of life has been doubled. It is not reasonable to blame physical science because people do not use to the best advantage the opportunities that it has provided. Nitrogen may be employed for fertilizing the soil or for killing men; universal schooling does not determine what people will read; wealth may be seized by a few instead of being used for the general good.

Human behavior is the concern of the psychological sciences. If it is asked why these have not accomplished more, a simple answer may be given. Psychology is a new science. The first chair of psychology in any university—held by the present speaker—was established at the University of Pennsylvania in this city less than forty years ago. The physical sciences have had centuries for their development, psychology only a single generation. It is futile to predict, but we are within our rights to hope, that the psychological sciences will in the end contribute in equal measure with the physical sciences to our knowledge and to its applications for our welfare. For example, it is not unreasonable to guess that the average productivity of each individual could be doubled and his happiness correspondingly increased, if he were selected for the work that he can do best, trained in the right way to do it, and given the most favorable conditions. We may further hope that in addition to its economic applications, psychology, even more directly than the other sciences,

will advance those things that are most worth while.

On a patriotic occasion such as this, we can date modern science and the new social era from the time of the discovery of America, the applications of science and the democracy made possible by them to the time of our revolution, the modern extension of scientific knowledge and its dominant place in civilization to the time of our civil war. It is our part to see to it that the world supremacy that our nation has now attained may mark the era in which science and the resources that it creates are used for the welfare of all.

AMERICA'S OPPORTUNITY IN CHEMISTRY

By Professor WILLIAM A. NOYES
UNIVERSITY OF ILLINOIS

SOME time ago statistics were published which stated that before the war there were thirty thousand chemists in Germany, five thousand in England, two thousand five hundred in France and fifteen thousand in the United States. I doubt the entire accuracy of these figures and the training of chemists and the standards for the profession differ so much in the different countries that it would be useless to attempt more than a very rough comparison of this type. It seems rather certain, however, that the nations mentioned ranked somewhat as indicated, in their chemical development. Before the war America had already laid good foundations for a rapid advance and this was greatly accelerated—perhaps too much accelerated—by the war. In Germany, on the other hand, the conditions for chemical development have not been favored and it seems reasonable for us to look forward to a time when America will take the first rank in chemistry. With this possibility in mind it is worth our while to inquire how Germany secured the position she holds and what we must do to secure a similar position.

Just about a century ago, in 1822, a young man, only nineteen years of age, went to Paris to study chemistry and had the good fortune to gain admittance to the laboratory of Gay Lussac. That was only eight years after the Napoleonic wars, when France and Germany had been bitter enemies, but chemistry was at a very low ebb in Germany and Liebig went to Paris to study chemistry with Gay Lussac, as his most intimate friend, Wöhler, went to Sweden to work with Berzelius, the greatest chemist of the time. There is such a thing as scientific heredity. It differs from physical heredity in that a man may choose his own father. Liebig chose Gay Lussac; Wöhler chose Berzelius; and several Americans still living are in the second or third scientific generation from Liebig.

In 1824 Liebig was called to Giessen as assistant professor of chemistry. There he founded a laboratory new of its kind in the world—a laboratory where teacher and students worked together intensely and enthusiastically in gathering new knowledge and building, systematically, advances in the science of chemistry. To that laboratory men came from all over the world and from that laboratory influences went out that touch every chemist and, indeed, every individual who has any part in our modern life.

Liebig's laboratory was small and crude in comparison with the palaces in which we work to-day and the knowledge of chemistry of the time was also small and rather easily mastered so far as Liebig thought this necessary for the beginning of constructive research. But to Liebig and to all those who have in-

herited something of his spirit the laboratory was not primarily a place for acquiring a knowledge of chemistry—it was a workshop where chemistry was made—where students did not so much follow the suggestions of some leader as where they gained an inspiration to strike out into new and untried paths of their own. He antedated a saying of Le Chatelier, "Young people are not receptacles to be filled; they are fires to be kindled."

One of the men who worked in Liebig's laboratory was A. W. Hofmann. In 1845 Prince Albert called Hofmann to London to teach in a newly founded college of chemistry. Ten years later he had as an assistant, William H. Perkin, a young man of nineteen, who was not content to merely work with Hofmann during the day but fitted up a small laboratory at home where he could work at night and on holidays. He thought there might be a relation between aniline and quinine because of an apparent relation between the formulas of the two, and on this basis attempted a synthesis of the alkaloid. We now know that there was not the slightest chance of success. Instead of quinine he obtained a colored compound. As he reports, chemists at that time did not think much of colored compounds and looked on them as impurities to be removed by bone black, or otherwise. Perkin was struck with the beauty of the compound and, perhaps partly because he was young and enthusiastic, he conceived the idea that the new color might be used as a dye. Fortunately, the father of Perkin had faith in him and furnished the capital to start the new industry. The problems the young man had to face in converting his laboratory preparation of mauve into a successful manufacturing process were varied and difficult. Benzene, which had been discovered in oil gas by Faraday in 1825 and was known as a constituent of coal tar, was not to be had as a commercial product and it was necessary to go to the manufacturers of gas for a crude product to be purified. Then the nitration of the benzene and the reduction of the nitrobenzene to aniline, known before then only as small scale laboratory preparations, must be carried out on a large scale in a factory. Even when the dye had been made, the dyers, accustomed only to the use of vegetable dyes, such as indigo, logwood and fustic, did not know how to use it and Perkin had to go into the dye houses and show them how to handle the material. All these difficulties were overcome and the foundation was laid for a great industry which has revolutionized the beauty of our wearing apparel.

A few years later Baeyer began an intensive study of indigo. Incidentally he discovered that by distilling certain compounds with zinc dust the oxygen they contain may be removed or replaced by hydrogen. Two other German chemists, in another university laboratory—notice that it was in *university* laboratories that Baeyer and also Graebe and Liebermann worked and not in factories—applied Baeyer's method to alizarin, the dye of Turkey red. They obtained anthracene and found the key to the structure of the dye. Shortly after, they made the dye synthetically and some attempts were made in Germany to manufacture alizarin. But it was W. H. Perkin, once more, with his years of experience as a manufacturer, who converted the laboratory synthesis into a commercial success.

With such a brilliant beginning it would seem that England should have continued the leader in the manufacture of artificial dyes, but long before the end of the nineteenth century Great Britain had lost all her initial advantage and Germany became preeminent in the production of synthetic colors.

When we look for the reason for this

surprising result we find it almost entirely in the laboratories founded on Liebig's ideal—laboratories where students learned the chemistry already known, it is true, but where, much more than that and as their prime object, teachers and pupils gave their energies intensely and incessantly to the development of an ever-changing science. Young men trained in such an atmosphere proved to be the very ones who could solve the varied problems of an industry which is so intimately connected with investigations in pure science.

In addition to the supply of trained chemists furnished by the universities, there grew up a most intimate connection between the university laboratories and the factories where dyes were made. In the olden times artisans and philosophers were entirely separated and the experimental method made little progress in science. That method is now thoroughly established and we see clearly that we can gain new knowledge only by bringing our ideas constantly to the test of agreement with objective facts. A condition somewhat similar to the old divorce between ideas and experiment still continues in some of our industries and universities. The "practical" men of the industries think they can get little help from science—and some scientific men think it is beneath their dignity to have connections with the industries.

While professors in German universities have continued to devote their energies to the development of the science of chemistry rather than to industrial applications of their knowledge, many of them have maintained intimate relations with the directors of factories and these relations have been mutually helpful. An illustration will help to make this clear.

Kekulé, one of the men who worked with Liebig at Giessen, proposed his theory of the structure of benzene in 1865. This has become, perhaps, the most important single fact guiding the work of the color-chemists even to the present day. Baeyer, who had studied with Kekulé, took up, in the same year, some work on isatin, an oxidation product of indigo. He tells us with what pleasure he had spent for a piece of indigo a birthday present of two thalers, given him when he was thirteen, and with what a happy, almost reverent feeling he drew in the odor of orthonitrophenol as he prepared isatin from the indigo by the directions he found in an organic chemistry.

After working with isatin and other derivatives of indigo for four years with good success Professor Baeyer dropped the subject for some years because his former teacher Kekulé published a paper in which he announced that he was attempting a synthesis of isatin. After waiting eight years, it became evident that Kekulé had not succeeded in his synthesis and Baeyer returned to the subject. Three years later he discovered a synthesis of indigo of sufficient promise for a patent and the Badische Anilin Soda Fabrik began at once an attempt to put the synthesis on a manufacturing basis. The chemists of the factory worked over the process from every possible point of view for fifteen years. The various steps of the process were greatly improved and more than a hundred patents were taken out but it was never possible to convert Baeyer's synthesis of indigo into a successful manufacture on a large scale. The original substance required for that synthesis is the toluene of coal tar and the annual production of this substance would be sufficient to make only one fourth of the indigo required in the world. As toluene is used in the manufacture of a great variety of other dyes and compounds, it is evident that any

considerable use for the manufacture of indigo would cause such an increase in the price as automatically to stop the manufacture.

The laboratory found its way out of this *cul-de-sac* by means of a discovery made in the chemical laboratory of the Polytechnic at Zürich, Switzerland—a laboratory which has given us many brilliant discoveries in chemistry and which is conducted on a high scientific plane, not on the theory that it should devote itself to so-called practical problems. By combining Heumann's discovery with another made by Hoogewerf and van Dorp in a university laboratory in Holland it became possible to manufacture indigo with naphthalene of coal tar as the starting point. Naphthalene, known to us all in the familiar moth balls, is abundant and cheap.

Even with the aid of these fundamental discoveries from the university laboratories the chemists of the factory continued to work incessantly on the problem for seven years before they were so sure of their ground that they recommended the building of a plant to make indigo on a large scale. The firm was then willing to spend four and a half million dollars on their plant for the manufacture of this single dye.

Many other interesting details might be given about the development of the manufacture of indigo but enough has been said to illustrate the intimate connection between the dye industry of Germany and the scientific work going on in university laboratories. Here, as in all branches of our modern national and international life, the only way forward lies in cooperation. If we can learn the full meaning of that, the possibilities of advance seem almost unlimited.

While I am emphasizing the training of men in methods of research and the intensive prosecution of research in our universities as the most essential foundation on which we must build if we are to take the first rank in chemistry, it does not follow that we must follow exactly the same lines that have been followed in Germany.

Nearly twenty-five years ago a man who had been trained as an undergraduate at the Massachusetts Institute of Technology and who had followed this with three years of work in the laboratory of Professor Ostwald, in Leipzig, was asked to take charge of a research laboratory for the General Electric Company at Schenectady. I have been told that for a time Dr. Whitney taught on Monday, Tuesday and Wednesday at the Institute in Boston, and worked in Schenectady on Thursday to Saturday, spending two nights a week on the sleeper going back and forth between the two places. It was not long before he discovered the method of "metalizing" carbon filaments for electric light bulbs and it is said this discovery was worth a million dollars to the company. The firm soon decided that they wished him to spend all his time at Schenectady, but he is still non-resident professor of chemical research at the Institute of Technology. As director of an industrial research laboratory, now probably the greatest of its kind in the world, Dr. Whitney has retained very much of the spirit and methods of the university laboratory. His men gather to discuss their research work, as the men of a university do, and some of them are engaged on problems which have no immediate industrial application in view. The contributions to the advance of chemistry which have come from that laboratory are very important and it is looked on as a model of its kind.

A few years ago our sailors were in danger of having to go out to meet the submarines, blind, because no one in America could make the optical glass necessary for their instruments. To whom did we turn in the emergency?

Was it to the manufacturers of glass? No! We turned to men trained for many years by research at the Bureau of Standards and at the Geophysical Laboratory in Washington where they had been studying silicates, not to make optical glass but to learn how the rocks in this old earth of ours have been formed. These men were able to solve the problem and within a few months, with the aid of a glass manufacturer, they had furnished six different kinds of glass required for the ordinary marine glasses and other optical instruments for the navy and army. Soon after, there was a call for a seventh glass with different properties. The men had worked out what is known as the triaxial diagram for silica, potash and litharge by means of which they could predict the relation between a glass made from these ingredients and its indices of refraction and dispersion. They located on this diagram the composition of a glass having the desired properties, put the ingredients together and it came out right the first time. Such is the difference between the old cut and dry methods of so-called practical men and a genuine scientific method.

The Royal Institution in London was founded in 1799 by Count Rumford, an American who had found Europe more congenial after our Revolutionary War. It has been stated that the support of that institution for the first century of its existence cost, on the average, only about twelve hundred pounds a year. But think, for a moment, what that six thousand dollars a year has meant to the world! It was there, in the early years of the nineteenth century, that Sir Humphry Davy made his startling discoveries in electrochemistry which laid the foundation for all our electrochemical industries. There, a few years later, Faraday discovered that a magnet thrust into a coil of wire generates an electric current and that an electric current may cause a magnet to rotate about it. These are beginnings from which all our modern electrical machinery has developed.

One of the features of the Royal Institution has been the giving of popular scientific lectures. The story is told that an old gentleman was accustomed to attend these lectures very regularly. He would come in and seat himself in one of the front rows and when the lecture was well started he would fall asleep and sleep all through the address. When the will of this old gentleman, John Fuller, was opened, it was found that he had left a bequest of ten thousand pounds to the Royal Institution "In memory of many happy and profitable hours spent there"—it sometimes pays to cultivate those who sleep through our lectures.

I have spoken of the absolute separation between the old philosophers and the artisans and of the somewhat similar attitude of those university men of our own time who wish to hold themselves entirely aloof from the practical affairs of life. There is, undoubtedly, some justification for this attitude for some of our university men have been drawn away from the pursuit of science to the pursuit of dollars, very greatly to the detriment of science. This is not altogether the fault of the scientific men. The annual per capita value of the material products of the United States is four times as great, in gold values, as it was in 1880. This means that the salary of a professor in a university should, in justice, be four times what it was in 1880. The wages of laboring men have gone up somewhat in the proportion that is just and the rewards of the leaders of our industries have certainly increased, at least in proper proportion, but the returns to academic men have not yet increased as they should. I think that I have made it clear that our great advances in industrial chemistry rest on the work of the universities for

their foundation. This seems to be well recognized and the great gifts to our laboratories from fortunes made in the industries are a concrete expression of this recognition, which we may hope to see increased. The same thought is slowly making its way into the minds of legislators, as shown by the increasing appropriations for state universities. Its recognition by Congress is still far from satisfactory, and unless this can be remedied the splendid record of the scientific bureaus of the government can not be maintained.

In one respect we may claim to have attained a better ideal than any other country. We have united all classes of chemists in a single society which has become much larger than any other chemical society in the world. By uniting our forces for publication and for the promotion of the interests of chemistry and of chemists we have demonstrated the very great advantages of cooperation. Our members sometimes object that we furnish them with a great deal of material which they can not use or in which they have no interest. In such a connection a comparison with the daily newspaper often comes to my mind. There are always many things in the paper for which we, as individuals, have no interest but the success of the paper depends on its appeal to persons with very varied interests and to the fact that each of these finds something of value. In France, the daily papers have, apparently, followed the plan of publishing a great number of different papers each of which is found agreeable to a comparatively small class of people. I am sure that most people who have followed these papers find them far less satisfactory than the large English and American dailies. Somewhat the same principle has been followed in publication abroad and especially in Germany. Our four journals cost our members only $15.00 a year, while the *Chemisches Zentralblatt* alone costs the members of the German Chemical Society $20.00. Only a comparatively small number of the papers giving an account of new research work are published in the *Berichte*, which corresponds most closely to our *Journal of the American Chemical Society*. At least eight or ten German journals would be required to get as good an oversight of chemical research in Germany as we can obtain for America from the two journals, the *Journal of the American Chemical Society* and *Industrial and Engineering Chemistry*. As our research grows in volume and quality, however, there may be some question whether we can continue indefinitely our policy of the past twenty-five years. Indeed, we already have a *Journal of Physical Chemistry, Journal of Biological Chemistry* and *Journal of the Electrochemical Society* as well as a considerable number of journals devoted to special fields of industrial chemistry.

During the year following the armistice a young man who had seen service in France wrote me, "I am not so happy as I was then," referring to the days when he was in the army. He had in mind that many nations were working together as one man to win the war and that the men did so in a spirit of patriotism and devotion to the cause which had disappeared as the opposing national and individual interests came to view in the peace conferences. Must this be so? We have seen that a dozen nations can unite for war. Is it impossible for them to work in cooperation for the common interests which bind them so closely together in times of peace. Capital and labor united in prosecuting the war. Is it not possible for them to see their mutual interest in working fairly together for the advantage of the community?

As we look back through the ages a fundamental principle stands out—that

nation or class or individual who is willing to forget his own personal advantage when it conflicts with the advantage of others, gains, in the end, most happiness and advantage for himself; but the nation, or class, or individual who seeks first his own advantage with no thought of the good of others loses all that is most worth while in life. And we shall see, as we think of it, that this is the simple lesson taught nineteen hundred years ago—"He that saveth his life shall lose it, but he that loseth his life shall save it."

ENGINEERING AND THE NATION

By Dr. D. S. KIMBALL

DEAN OF THE COLLEGE OF ENGINEERING, CORNELL UNIVERSITY

THE story of man's upward progress from savagery to civilization is largely the story of his efforts to develop tools wherewith to subdue a stern, and on the whole, an unfriendly environment. That this fact has been deeply impressed upon him is evidenced by his recognition that this progress is marked by certain special improvements in his tools and methods; hence we speak of the Stone Age, the Bronze Age, the Iron Age and the Age of Steel. And it is quite evident that we are even now passing into a higher, and we hope a better, stage of civilization, the metallic index of which we can even now dimly visualize. It is true of course that certain of the older nations attained a high degree of culture with a handicraft background, but such culture was necessarily confined to a very few, the vast majority toiling as slaves in order that a limited number should have the things of life all men prize. But there is no record of widespread physical well-being, education and intelligence supported by handicraft; and axiomatically as the tools of industry become more and more primitive the status of the worker approaches more and more that of the slave.

Industrial development has progressed along three well-defined lines, namely, *labor-saving* machinery, *time-saving* machinery and machinery for *transmitting intelligence*. All three of these lines of endeavor have occupied men's minds from time immemorial, but it has remained for the scientists and the engineers of the last century and a half to really make machinery and scientific apparatus that have revolutionized not only our manner of living but our *ideals* of existence as well. It is fitting, therefore, at the close of the third half century of our national life during which these great developments have occurred to review the progress we have made since the last great celebration in this city that marked the hundredth milestone of our national existence.

From the very beginning of his mundane career man has recognized that he could greatly help himself by bringing to his aid the forces of nature, such as wind and water. The development of prime movers such as the steam engine and the gas and oil engine and the harnessing of water powers is a direct result of this ancient need. The progress in this direction during the last fifty years is most remarkable. The great Corliss engine built by George Corliss himself to operate the machinery of the Centennial Exposition of 1876 was considered to be a mammoth machine of epoch-making importance. It was rated at 1,400 horsepower. To-day we have single hydroelectric units that develop 70,000 horse-

power, and steam-driven turbo-generators sets that develop 60,000 horsepower in a single unit are becoming commonplace. The first locomotives weighed three or four tons, while modern locomotives weighing 300 tons are now quite common. The *Clermont* would barely make a tender for the *Leviathan,* and as high as 100,000 horsepower has been installed in a single torpedo-boat destroyer. More important still Mr. Fred Low computes that the total installed prime mover capacity of the United States to-day is so great as to place, potentially at least, at the disposal of every man, woman and child of this great country the equivalent labor of nearly 150 slaves. If labor-saving machinery may be taken as an index of civilization, and obviously it can be, we stand to-day on an economic plane vastly higher than any of our predecessors of slave-owning days.

By *time-saving* machinery is meant all that vast array of machinery that fills our factories and to a large extent tills our soil. These machines are the lineal descendants of the stone ax and other primitive tools of production. It should be noted that this class of machinery is *labor-saving* only as it is driven by labor-saving machines, such as the steam engine, water wheel, etc. Any description of this vast array of productive machinery is far beyond the limits of this paper. But it should be noted that through this machinery man has been able to multiply his productive effort many fold, and the term "mass production" properly describes our modern conception of producing the necessities and luxuries of life. No such production has ever been accomplished in the history of man and the limits to these methods are as yet not in sight.

The modern development of apparatus for transmitting intelligence is again the culmination of long-seeking effort which extends from the savage making signals with puffs of smoke down through the use of the semaphore, the heliograph, the telegraph and the telephone to the radio, in one continuous thread of development. The solution of this age-old problem is a thing to marvel at for its perfection. Obviously its greatest effect is to speed up the entire industrial machine and to add to its effectiveness.

It would be superfluous to recount the many accomplishments of applied science as represented by the work of engineering in these three fields. In transportation and communication it has almost eliminated time and space and made the whole world neighbors. It has given progressive nations physical comforts undreamed of by our ancestors and has filled their territories with the good things of life. I am not unmindful of the great progress that has been made in other fields of applied science, such as medicine and agriculture; nor of the hope that progress in these fields holds out for humanity. But nevertheless engineering is the great outstanding feature of modern civilization, and all other fields of applied science depend, perhaps, more than is usually realized upon engineering. The development of the modern printing processes alone, which are almost purely engineering in their character, has done more to disseminate knowledge in all branches of learning and has, in fact, contributed more to civilization than any other development, excepting only the steam engine.

The success of the engineer in applying science to the solution of his peculiar problems has not gone unnoted by workers in other callings. It was to be expected that correlated fields of endeavor such as industrial administration would be greatly influenced by these new methods of attack. But the engineering method has long since outgrown the bounds of the workshops and factory to such a degree that the words "engineer" and "engineering" have all but lost

their original significance. We have "efficiency engineers," "sales engineers," "human engineers" and so over a range of activity that is truly startling. Engineering, in fact, has become synonomous with accomplishing results, with "getting things done." It has become a method of thinking by which men proceed to the solution of their problems through orderly reasoned methods based, so far as possible, upon known facts; and speculative philosophies, so long the stumbling block of industrial achievement, have no place in these methods.

But more important than this, more important than the physical comforts these methods have bestowed is the manner in which modern applied science has enlarged our vision of humanity and its problems and the consequent effect upon our ideals of life on this planet. It may be logically questioned as to whether man has made *intellectual* progress since the golden days of Athens, but certainly we have widened our ideals. Or rather we have admitted among our ideals possibilities that, while recognized as desirable by our progenitors, were pushed aside because of expediency. All history indicates that men's ideals have always been limited and modified by the problems of making a living and, in general, as the tools of production have been improved and living conditions made consequently easier, more tolerant ideals have prevailed. The ancient Greeks with all their intellectual development knew of no way in which to support their intellectual life except by slavery. We, in an age when productive methods are immensely more highly developed and in a land where natural resources are ample, hold slavery to be not only unnecessary but actually unmoral. The ideals of all ancient civilizations were *ideals of necessity*. To a certain extent this is still true of our civilization. But for the first time in the history of the race there is held out a hope that through modern methods of production we may yet attain an ideal of existence that has long occupied man's mind, but because of the limitations of his industrial methods has remained a Utopian dream.

If I read the ideals of American democracy aright we are committed in this country to an effort to attain universal well-being where every man, woman and child shall have enough to eat, drink and wear, proper housing, and some measure, at least, of mental and spiritual development. And so far as can be seen at present the only hope that this can be accomplished lies in present-day engineering productive methods; and this is the reason for the faith that is in us who believe in the development of science, pure and applied, to the uttermost.

And therefore as we review the progress of engineering during the past fifty years the future is bright with hope. True, there are many difficult problems yet to be solved. We have solved in some degree the problems of production, but we have made little progress in the intelligent distribution of the proceeds of industry. But there would seem to be no reason why these difficult problems should not yield to the same rational methods of thought that have already solved some very difficult problems. It would be interesting indeed if we could lift the veil that hides the future and see what engineering will be like when Philadelphia celebrates the two hundredth anniversary of the birth of this nation that before all others holds out the hope of universal well-being.

THE ATMOSPHERE: ORIGIN AND COMPOSITION

By Dr. W. J. HUMPHREYS
U. S. WEATHER BUREAU

It will be convenient to consider first how the earth came to have an atmosphere, and after that in some detail what this atmosphere is.

To begin, then, not at the ultimate beginning, but as far back as actual knowledge permits, we believe that everything that we call matter consists of some combination or assemblage of two things as yet unresolved—the electron and the proton, the negative and the positive electric atoms, or at most, these charges and their carriers. Whether these ultimate (for the present) elements also are "matter" is, perhaps, only a question of definition. At any rate they are entities, and the most elementary of which we have any definite evidence. We have no knowledge of the origin of either the electron or the proton. They can exist separately, from which one might infer that they may have originated independently. On the other hand, the equality of their charges suggests simultaneous origin in equal numbers. But be that as it may, normally the atom of every element from hydrogen to uranium, and all their compounds from the simplest to the most complex, consist of equal numbers of electrons and protons. Even in those exceptional cases where the atom is deprived of one or more of its extranuclear electrons the electrons themselves are not lost but kept close by—they or others—and organic union with them re-established the instant such union is not actively prevented. Hence, wherever matter occurs in great quantity, as in a star or a planet, one may expect to find every possible combination of electron and proton, that is, all the chemical elements and also such of their compounds as the existing temperature and other conditions may favor. Doubtless, therefore, every heavenly object, however nebulous or condensed, has within itself, as certainly our own sun has, the makings of an atmosphere. Evidently, then, when the earth was pulled out of the sun by the tidal action of a passing star of much greater mass there were taken along the hydrogen, oxygen and nitrogen of the ocean and the air as well as the iron, silicon, aluminum and other elements of the lithosphere.

The portions of the sun thus pulled out by tidal action broke up, if we accept Jeffreys' logic,[1] into separate masses each of which soon became a liquid sphere surrounded by an envelope of vapors and gases. In the case of the earth, it appears that the gravity pull of the liquid sphere was sufficient to retain the water vapor, if such existed, and all the gases except hydrogen and helium.

After a relatively very short period, only a few thousand years, a more or less stable crust formed, consisting essentially of rock material, the iron and other heavy substances, through the action of gravity, having formed the inner core. The surface temperature then rapidly fell to a value comparable to that which seems to have obtained ever since, leading to the condensation

[1] H. Jeffreys, "The Earth," Cambridge University Press, 1924.

of most of the water vapor, if it existed in large quantity, and to a well-nigh perfect conservation of all atmospheric gases, including now even hydrogen and helium.

Whether this primordial supply of free air and free water vapor was great or small, we do not know. But whatever these original quantities, there was also a never-failing fresh supply of all, or practically all, the elements and compounds that constitute the atmosphere as it exists to-day, with the probable exception of oxygen. For the crusting over of the earth must have been accompanied and followed by vast lava flows and other forms of eruptions that gave off then, as they do now, great volumes of steam, carbon dioxide, nitrogen, hydrogen and other gases, except, presumably, oxygen, each of which, or its elements, had been absorbed, occluded, combined or otherwise taken up by the rocky materials while in their previous gaseous or liquid state.

Since free oxygen has not been found in volcanic gases known to be uncontaminated by admixture of atmospheric air, and since it presumably could not exist at high temperatures in the presence of free hydrogen and free sulphur, it seems that the oxygen of the air can not be of volcanic origin, at least in its present state. It may be that the original supply of oxygen was more than enough to combine with the available hydrogen and other oxidizable substances at and near the surface of the earth, and that from the beginning our world always has had an oxygen atmosphere. It is true that through photosynthesis plants give off considerable quantities of oxygen; hence the oxygen of the air might be accounted for in this way, provided plant life could have started without the presence of this gas in the free state, a result that seems quite possible, since many of the lower forms of life thrive where this element is not free, and yet under the stimulus of light evolve it from one or more of its compounds, especially water. Finally, lightning produces a little free oxygen through its action on water, and so also may ultraviolet light, but these sources appear to be insignificant.

Presumably, then, from the very beginning of its independent career the earth has had an atmosphere of nitrogen, oxygen, water vapor, carbon dioxide and various other gases. But even if they ever had been taken up wholly by other materials of the earth, which seems most unlikely, they later would have accumulated to a greater or less extent through chemical reactions, as manifested by volcanoes and biologic activities.

Now that we have seen that the earth must have an atmosphere of some kind, partly regenerated, we are sure, for we see it coming out of volcanoes, and partly primitive, perhaps, we next may inquire what the present composition of that atmosphere really is.

The oldest considerations of the air known that possibly can be called scientific are those of the ancient Greeks. They believed it to be a single, homogeneous substance, or, more exactly, an element—one of four that singly and variously combined make up all objective things. In effect, however, they declared the atmosphere to be complex; a belief implied, though perhaps not clearly recognized, in the correct assertion by Aristotle that clouds and rain are produced by condensation out of the air of aqueous vapor that previously had arisen from the surface of the earth. For more than twenty-two centuries, then, perhaps for much longer, it has been known that the atmosphere is a mixture, at least to the extent of being part water vapor and part something else; and for over two thousand years after the days of Aristotle, this is all that was known about its composition.

The first of the relatively permanent gases found to be a constituent of the atmosphere was carbon dioxide. The investigations that led to this amazing result were begun in 1751 by Joseph Black, while a student of medicine in the University of Edinburgh, and published in 1755 as his thesis for the degree of M.D. It is interesting to note in passing that Dr. Black's astonishing discovery that placed him among the scientific immortals was not anomalous, and indicative, as one might suppose, of a haphazard or even perfunctory selection of thesis topics, but a thing that incidentally evolved from a searching study of the use of alkalis and lime water in the treatment, then advocated, of urinal calculi.

The next advance in our knowledge of the composition of the atmosphere, the discovery of nitrogen, also was made by a medical student, Daniel Rutherford, in the University of Edinburgh, and published as a thesis for his degree in 1772. His investigation was begun at the suggestion of Dr. Black, the discoverer of carbon dioxide, or fixed air as he called it, then professor of chemistry at the University of Edinburgh. In the main, Rutherford first added as much phlogiston as possible to a confined volume of air, that is, burned out the oxygen, as one says to-day, but which he could not say as oxygen at that time was unknown, then absorbed the carbon dioxide, if any had been produced, with a suitable alkali, and finally examined the properties of the mephitic air—nearly pure nitrogen, as we now know—that remained. Like Black's work that led to the discovery of carbon dioxide, Rutherford's investigation also had its medical aspect. This portion of his study, however, appears to have given only negative results, for in his thesis he says: "I had intended to add something regarding the composition of mephitic air, and to seek for a reason for its unwholesome effects, but I have not been able to find out anything with certainty."

Almost immediately after Rutherford discovered the nitrogen of the atmosphere, both Scheele and Priestley found its other major constituent, oxygen; Scheele before 1773, apparently, and Priestley on August 1, 1774. Thus the priority of this discovery rests with Scheele, but, on the other hand, the priority of publication belongs to Priestley by about a year.

As early then as 1775, the atmosphere was known to consist largely, and believed to consist almost wholly, if not entirely, of (1) water vapor, recognized from antiquity; (2) fixed air, or carbon dioxide; (3) mephitic air, or nitrogen; (4) dephlogisticated air, or oxygen. Thus the problem of the composition of the atmosphere appeared to be wholly solved, and here our knowledge of it remained fixed, except in respect to a few variable impurities, for well over a hundred years, or until 1894, when Lord Rayleigh and Sir William Ramsay startled the scientific world by telling us of that strange element in the air, argon, that in total mass exceeds by several fold the whole of the water vapor, carbon dioxide and every other atmospheric constituent all combined excepting only the nitrogen and oxygen. Soon after this, and in quick succession, all the other inert gases, neon, helium, krypton and xenon, were found likewise to be interesting parts of that atmosphere which formerly we thought we knew so well. Careful analyses of the atmosphere show also the presence of free hydrogen, but the amount found, always very small, has varied so widely that its constancy is questioned. Its production by volcanoes certainly is irregular, as likewise are some of the ways by which it may be consumed. However, it seems always to be a part of the lower air; by volume seldom if ever less than one in 1,000,000, or greater than one in 5,000.

The value most frequently quoted is one in 10,000.

Finally, the air is full of electrons, radioactive gases, spores of many kinds, cosmical dust and terrestrial dust of every conceivable variety.

The volume percentage composition of dry air at the surface of the earth and freed from impurities is, approximately:

Nitrogen	78.03
Oxygen	20.99
Argon	0.9323
Carbon dioxide	0.03
Hydrogen	0.01
Neon	0.0018
Helium	0.0005
Krypton	0.0001
Xenon	0.000009

The values here given for the inert gases are by Moureu and Lepape, *C. R.*, July 19, 1926.

The amount of water vapor in the atmosphere varies widely, as every one knows, from almost nothing when the temperature is very low, to at least 5 per cent. by volume at the surface. The average amount in the whole atmosphere, however, is the equivalent, roughly, of a sheet of water 2.6 cm. deep over the entire surface of the earth.

From the above values, and various other pertinent factors, such as molecular weights, barometric pressure, distribution of temperature with height, extent and elevation of continents, etc., one can compute the approximate mass of the atmosphere as a whole and of each of its constituents. These values are given in the table following.

One of the constituents listed in this table, *viz.*, water vapor, belongs almost wholly in the lower air. This is because the vapor capacity of a given volume decreases very rapidly with temperature, and temperature in turn with increase of height. Ozone, on the other hand, is mainly in the upper air. At what height it is most abundant we do not know, but probably far beyond the highest clouds.

Mass of the Atmosphere and of its Constituents

Substance	Volume per cent. dry air	Total mass
Total atmosphere		51100000 × 10^{11} kg.
Dry air	100.00	50967400 " "
Nitrogen	78.03	38722986 " "
Oxygen	20.99	11596239 " "
Argon	0.9323	618814 " "
Water vapor		132600 " "
Carbon dioxide	0.03	21658 " "
Hydrogen	0.01	1291 " "
Neon	0.0018	689 " "
Krypton	0.0001	128 " "
Helium	0.0005	80 " "
Ozone	0.00006	30 " "
Xenon	0.000009	17 " "

Since the values in this table were more or less independently determined it could not be expected that the percentages of the constituents (not quite everything in the atmosphere) would add up exactly 100, nor that the combined mass of these several parts would be precisely the same as that of the whole. These deviations, however, are very small, indeed well within observational and experimental errors.

It is the powerful absorption band of ozone centered at around wave length .25 μ, and spreading widely on either side, that limits the ultraviolet extent of the solar radiation received at the surface of the earth. From a comparison of this limitation at different solar altitudes with each other and with ozone absorption of radiation in the laboratory, it has been estimated that if all the ozone in the atmosphere was gathered into a single layer, at standard temperature and pressure, this layer would be only about three millimeters thick. There is no strong corresponding absorption of the ultraviolet in a path of even several miles of surface air.[2] Hence we are sure that ozone is confined almost exclusively to great heights.

The percentages of the other constituents of the atmosphere remain practically constant throughout at least its

[2] R. J. Strutt, *Nature*, V. 100, p. 144, 1917.

lower ten to twelve kilometers, except as slightly altered by the rapid decrease of water vapor with increase of height. This substantial constancy of composition, despite wide variations in molecular weight, is owing to constant mixing through wind turbulence and thermal convection. But thermal convection extends to the height of only ten to twelve kilometers in middle latitudes, and to, say, fifteen kilometers in tropical regions. Beyond these levels, where temperature is practically constant with height and convectional mixing therefore impossible, the percentages of the heavier constituents except ozone decrease with increase of height, while those of the lighter increase. The ozone, it is believed, is formed by the action of radiation far in the ultraviolet on the upper levels of oxygen, hence, and because also of its slow, spontaneous decomposition, its density distribution is believed to be radically different from that of any other atmospheric gas.

The composition of the highest portions of the atmosphere, that part beyond one hundred kilometers above the surface of the earth, is very imperfectly known. One naturally would suspect an increasing percentage (not quantity, of course) of nydrogen with gain of height, but it may be that this gas is all consumed at comparatively low levels. Even if it got beyond the clouds it still would have the gantlet of ozone to run before reaching a safe level. Possibly some of the mere trace of water vapor at great heights may be dissociated by ultraviolet radiation and a little hydrogen and monatomic oxygen thus produced. We are not sure, then, whether there is or is not any hydrogen in the outer portions of the atmosphere. It is not indicated by auroral spectra, nor with certainty by the spectra of meteors. However, this is not conclusive proof of its absence, since neither meteors nor auroras reveal helium either, though surely it must be in the outer atmosphere, as it runs no chemical danger whatever, as hydrogen would, on its way thither.

Meteors tell us nothing positively about the composition of the outer air. Auroras, on the other hand, give us some very definite information on this subject. The normal base of auroras is about one hundred kilometers above the earth. Here, and for perhaps several hundred kilometers beyond, they show, by their spectra, the presence of nitrogen and of oxygen, the former by several bands, the latter through the famous "auroral line," as first explained by McLennan and Shrum,[3] of the University of Toronto.

But how, one asks, can oxygen, in adequate quantity, reach such heights? We do not know. It has been inferred from the heights at which meteors are fired that the temperature of much of the upper air must be surprisingly high,[4] equal at least to that at sea level on a hot summer day, But balloon soundings up to thirty-five kilometers or thereabouts show no evidence of such condition. Besides, the necessity for so great a density of the upper atmosphere to fire meteors as this high temperature would provide has been questioned.[5] One therefore asks whether there is any other way than through the expansion incident to high temperature by which an appreciable amount of oxygen can be got into the outer atmosphere. Possibly so. At any rate, since the auroral line appears to be due to monatomic oxygen, being a sharp line and not a band, one may suspect that the very high atmosphere contains an appreciable amount of this particular substance—a gas of but half the molecular weight of ordinary oxygen and capable therefore of reaching far greater heights. In the lower atmosphere oxy-

[3] *Proc. Roy. Soc.*, A108, p. 501, 1925.

[4] Lindemann and Dobson, *Proc. Roy. Soc.*, A102, p. 411, 1923.

[5] Sparrow, *Astrophys. Jour.*, 63, p. 90, 1926.

gen is diatomic; somewhere in the high atmosphere much of it is triatomic; and now we suspect that at still greater heights, and owing to the action on one or both of these forms, and possibly also on traces of water vapor, of excessively short wave-length insolation, it may be monatomic. Certainly the production of ozone requires the breaking down of diatomic oxygen to monatomic, some of which may, in the rare upper atmosphere, long persist unchanged.

There remains one other hint about the composition of the outer atmosphere worth mentioning, namely, its electrical conductivity, as indicated by certain wireless phenomena. This conductivity is owing, we believe, to a relatively great number of free electrons—half a million per cubic centimeter, perhaps, an enormous number, and yet small in comparison with that of the atoms present.

Our knowledge of the composition of the lower atmosphere from the surface of the earth to the height of at least fifteen to twenty kilometers, is reasonably satisfactory, except in respect to condensation nuclei and the so-called impurities; but as the upper air grows thinner, even more rapidly does our information about it become less. In many ways the state and composition of the air far beyond the highest clouds profoundly modifies not only radio communication, but even life itself, both animal and vegetable, and we earnestly want to know more about that state and that composition. Some day we shall know more about them.

THROUGH A CHEMICAL LENS

By Dr. K. GEORGE FALK
HARRIMAN RESEARCH LABORATORY, THE ROOSEVELT HOSPITAL, NEW YORK

THE life process of an individual of any species represents to the human intellect a series of changes occurring in a number of structural units, changes complex and confusing to the understanding, but in reality interwoven to produce a moving pattern which is systematic and orderly.

The various structural units undergo changes which are chemical in character. The study of these individual chemical reactions has shown that they obey the same laws and regularities and show the same relations as do the chemical reactions of so-called inanimate nature. This does not mean that all the reactions which occur in life processes are understood. In fact, the behaviors of very few can be explained satisfactorily. It does mean that the changes which permit of study are found to be chemical in the sense that the same or similar reactions outside the living organism are chemical. The realization of this fact simplifies the consideration of the chemical changes. It is not necessary to develop a new chemistry, such as a chemistry of living matter or of the changes occurring in living matter. The chemistry which has been developed in the laboratory with materials not immediately derived from living matter is all-inclusive and is sufficient for the study, consideration, classification and comparison of the chemical changes in life processes. The evidence for the simpler substances and changes is quite satisfactory. On the other hand, the direct evidence that the very complex changes follow the chemical laws developed on the basis of the simpler reactions may be incomplete in many cases, although all the evidence available points in the same direction. It will therefore be assumed that the complex as well as the simple reactions which occur in life processes obey the same chemical laws as do those outside the living organism. This statement must not be stretched to unreasonable limits. Possible chemical changes connected with thought processes, with consciousness, whatever may be meant by the term, are not included. Nothing will be said about these, because nothing is known.

The limitations of the chemical viewpoint must be realized in order to obtain a proper perspective of the ground to be surveyed. Changes in chemical compositions under various conditions are included. The substances involved may be simple or complex in composition, individuals or mixtures, colloidal or non-colloidal. But nothing is said of the structure of the living matter of which these substances form not only a part but the whole, and in which they may be said to react. This structure or form is obviously of importance in many ways. For one thing, it makes possible the recognition of the material, frequently with the unaided eye, practically in every case by the microscope.

This is not the place to enter into a detailed discussion of structure as shown by the microscope, and function as evidenced by certain chemical changes. Their relative importance, their interdependence, their reciprocal influence, merit a much more extended treatment than is possible in this connection. Just as the question of priority between the hen and the egg was settled by the biologist, so it is probable that the problem of structure and function in living organisms will ultimately be satisfactorily solved. The physical form taken by the materials to make possible the

continuance of the life process is outside the field to be discussed here. To present the matter in the form of a crude analogy, a comparison may be instituted between a university and a mausoleum. Both may have the same external structure or physical framework composed of the same materials. In the one case there is a continual activity, interchange with the outside environment, change and development of the material within the structure, and, in general, various forms of activities susceptible to quantitative measurements if the characters of the materials under examination were properly understood. In the other case, the changes occurring are few, comparatively easy to follow and simple in character. There is none of that bustling activity seen in the former case. These two sets of structures and activities may be compared to chemical changes in living and dead matter, or, to go a step farther, to changes of animate and inanimate nature. It is obviously inadvisable to extend the comparison too far, but it is desirable to form a picture of the minor importance that structure as such plays in the chemical changes in life processes as presented here.

The interpretation of life processes in terms of chemical reactions or of the changes in composition of various components, is, in the opinion of many, an object much to be desired. Such an interpretation should not only be useful because of the presentation of a different point of view in connection with certain phenomena of nature, but might add to a more fundamental understanding of the processes involved. The chemical reactions and chemical changes are necessarily an important and perhaps the predominating feature of the biological developments which are continuously occurring in active life processes.

The biological development of an individual of a given species when grossly considered represents a systematic and orderly development. Conception, birth (or initial formation of the individual), growth or development, and finally death, may be mentioned as a few of the striking events, while in between the changes occur steadily, and, with careful observation, can be followed from day to day, or during as short periods of time as may be desired. The gross changes are known to everybody with more or less exactness. The biologist follows the changes more in detail, and, on the basis of the study of the cell and its structure, has developed the science of living organisms from a structural point of view.

The question now arises as to the bearing of chemistry upon the study of the changes occurring in living organisms. The chemist considers these changes in terms of chemical reactions and changes in chemical compositions of the constituents. That is to say, the life processes of an individual, viewed by the so-called scientifically untrained man-in-the-street as a series of well-known, obvious, continuous changes in size, appearance and ability to act, by the biologist as changes in cell structures, as cell growths, as interactions between cell groups, and as coordinated interactions which culminate in the life process, will now be thought of as chemical actions and interactions of the constituents of the living organism. The life phenomena will be considered through the medium of the chemical reactions which occur. These phenomena will be watched and studied through a "chemical lens." The interpretations of the life processes in terms of chemical reactions and changes will be based upon the significance of the observations to the extent that these observations, acting as the chemical lens, will permit them to be perceived.

The chemical lens consists of the chemical changes and reactions which are studied. A chemical lens may be imperfect and not reproduce truly the object under consideration. It may be

cloudy and opaque and therefore permit only a part of the knowledge to penetrate; it may be selective in its absorption and transmission and reproduce therefore only portions of the phenomena; it may refract strongly, distort the image of the object and therefore transmit a distorted knowledge; its field of view may be very small and therefore furnish only limited and incomplete knowledge of the object under investigation. In general, the possible imperfections and troubles which are encountered with the optical lens may be paralleled by this chemical lens. If the chemical lens is so imperfect, it may well be asked why an attempt should be made to use it in the consideration of biological processes. The chemical natures of the processes involved are of the utmost significance, and while the chemical lens at the present time is admittedly imperfect it does yield results of interest and of value. A perfect chemical lens will furnish a complete representation of the chemical knowledge of the object studied as well as a perfect interpretation from the chemical point of view. This perfection of chemical lens, of representation of the object and of interpretation is obviously far from true for life processes. Some of the pictures which have been obtained with the chemical lens will be outlined.

The chemical composition is naturally the first property to be studied by means of the chemical lens. Much work of this sort has been done. The inorganic constituents of matter from various living sources have been determined, and the organic constituents have been extensively studied. The results of these chemical analyses are important and of great value. At the same time they leave a feeling of incompleteness for the consideration of living matter as such, or of the life process. The chemical lens here does not transmit enough information for a satisfactory mental image of the changes, in comparison with the living object under investigation. The reason therefore may be placed on the chemical lens. The methods of study in these cases are not sufficient to produce the clear mental image desired. It may be of interest therefore to consider these methods of study (or chemical lens) somewhat farther.

The estimation of the inorganic constituents present in living matter under various conditions and at different stages of growth has unquestionably been of value. The importance of these constituents has been made clear, and especially the significance of very small amounts of certain of the inorganic elements has been emphasized. While their importance is recognized, the ways in which they act and the parts they play in the living organisms are frequently quite obscure. The chemical lens shows that they are present, that their presence is essential for the continuance of the life processes, but only in rare cases has permitted the attainment of the knowledge of the parts they play and the manner in which they play them.

The matter is immeasurably more difficult with the organic constituents of living organisms. Many of these organic substances are inherently unstable and undergo changes in definite ways which are essential for the continuance of the life processes. In attempting to isolate these substances in the laboratory, changes may occur because of various treatments, so that the materials finally isolated may bear only slight resemblance to the substances present in the living organism. The chemical lens here has modified the substances under investigation and has changed their appearance and properties. It has been one of the aims of this branch of chemistry to improve the methods of isolation (the chemical lens in this case) so that the substances isolated may be identical with those present in the living organism (a perfect chemical lens). Much progress has been and is being made and it

may be said that the perfect chemical lens is being approached in a number of cases.

A comparison of the chemical properties and behaviors of substances of inanimate and of animate nature will serve to bring out the inadequacy of the method of chemical analysis for following the changes in the latter phenomena. The chemical analyses of mineral substances in many cases suffice to characterize them. Their states are fixed for all practical purposes, and chemical analysis at one time will show the same as chemical analysis at another time. Changes which take place in the course of time in most cases occur extremely slowly. With substances of animate nature, the time factor is of great, if not predominating, influence. Chemical analysis at any one period of the life process is important but only characterizes the material at that time. Life is kinetic, it is moving, changing, and the substances in living matter move and change. Repeated chemical analyses at different periods of the life process must be carried out. But this is not the only way in which the time element enters into the study. Because of the instability of many of the substances involved in the life process, their isolation for the purposes of identification and study will be accompanied by changes. Many of the substances present in animate nature are not as stable as most of those present in inanimate nature, and methods of chemical analysis must take account of this fact. The chemical lens through which many facts of the mineral world are observed satisfactorily is not sufficient for many facts of the world of living matter. For example, the phenomena of substances in the colloidal state need new or modified methods of study or a more complete chemical lens.

It is evident that it is extremely difficult to develop a chemical picture of the whole of a life process. A chemical analogue of the life process is to seek. In the past six years Miss Helen Miller Noyes and the writer have been developing a line of work at the Harriman Research Laboratory which may perhaps be accepted as a contribution to this study. A new type of chemical lens has been developed, and the results of the study of the chemical properties by this method when compared with some of the results of biological study may be of interest and permit of further developments. Only an outline of this method can be presented here; for details the communications presented elsewhere must be consulted.

The chemical changes during the life process in any one form of living matter proceed in certain definite ways peculiar to that form of living matter, although many other changes in the material are possible. The directive agencies are assumed to be "enzymes," substances which, while not as yet isolated in a pure state or as definite compounds, take part in the reactions of living organisms with the result that products are produced necessary for the continuance of the given life process. Preparations from living matter are able in the laboratory to produce definite chemical changes in complex substances as well as to bring about chemical reactions in simpler substances. This fact proves that enzymes and enzyme actions are not mere abstractions invented for the purpose of mentally accounting for certain changes occurring in the course of life. It may well be possible to go to the other extreme and to consider that enzymes and enzyme actions are the chemical essentials of life processes. A study of enzyme actions may therefore furnish a more useful chemical lens, in the sense of approximating more closely than other chemical methods which have been used the actual changes and behaviors of living matter.

Without entering into the details of the work at the Harriman Research Lab-

oratory, a few of the general principles developed may be given. It was realized that the chemical changes brought about by preparations from living matter (containing enzymes) could not in general be the same as those changes which occur in the living organism. Simple chemical changes were therefore chosen for the *in vitro* tests, changes which, while perhaps only remotely connected with changes in living organisms, nevertheless might be expected to show a number of the different enzyme actions of the organisms or at least to parallel them. Conditions of testing which modified the materials as little as possible were developed. Various normal tissues and tumors from a number of different animals were studied.

After testing various enzyme actions of the materials, the hydrolytic actions on a number of different esters (ten) under fixed and comparable conditions were chosen as most useful and satisfactory. It was recognized early that the actual amounts of the enzyme actions were not the most important factors in the study, although these were interesting and at times useful. Rather, the comparative hydrolytic actions of a given material on the different esters, expressed most readily in terms of percentages of the largest action of that series, were found to be most significant. A method of plotting the results was developed which permitted the presentation in the form of a curve of ten (or any number) of these ester-hydrolyzing actions of any one tissue and the comparison of this curve with the curves of other tissues. These curves or "pictures" of relative enzyme actions were significant of certain tissues and tumors. Frequently, where the absolute action of a given tissue from different animals of a species varied greatly, the curves of the relative actions were found to coincide closely.

The results obtained by means of this chemical lens in a number of cases paralleled the views obtained by other methods of study; in other cases apparently led to opposite conclusions. One example of the latter will be given. In the study of tumors, both from animal and human sources, the chemical enzyme study (chemical lens) showed that various tumors from different sources which histologically were found to be quite different, gave the same curves of relative enzyme actions, while on the other hand, a number of tumors which were the same histologically gave entirely different enzyme curves.

It is obviously impossible to say that either of these methods of investigation is wrong. The histological results are based upon long years of study and have proved most useful in many ways, but it can not be said that they are complete or final. The enzyme method of study is a comparatively recent development and it is perhaps too early to discuss the exact significance of the results. The chemical lens in this case is still too new to make possible a statement of the field which it covers, the light which it transmits, and its possible imperfections. It may be said, however, that it appears to offer an additional method of study of life processes, and perhaps approach more closely from a chemical standpoint the properties and changes which occur in living organisms.

MONGOLIAN MAMMALS OF THE "AGE OF REPTILES"

By Professor WILLIAM K. GREGORY

AMERICAN MUSEUM OF NATURAL HISTORY

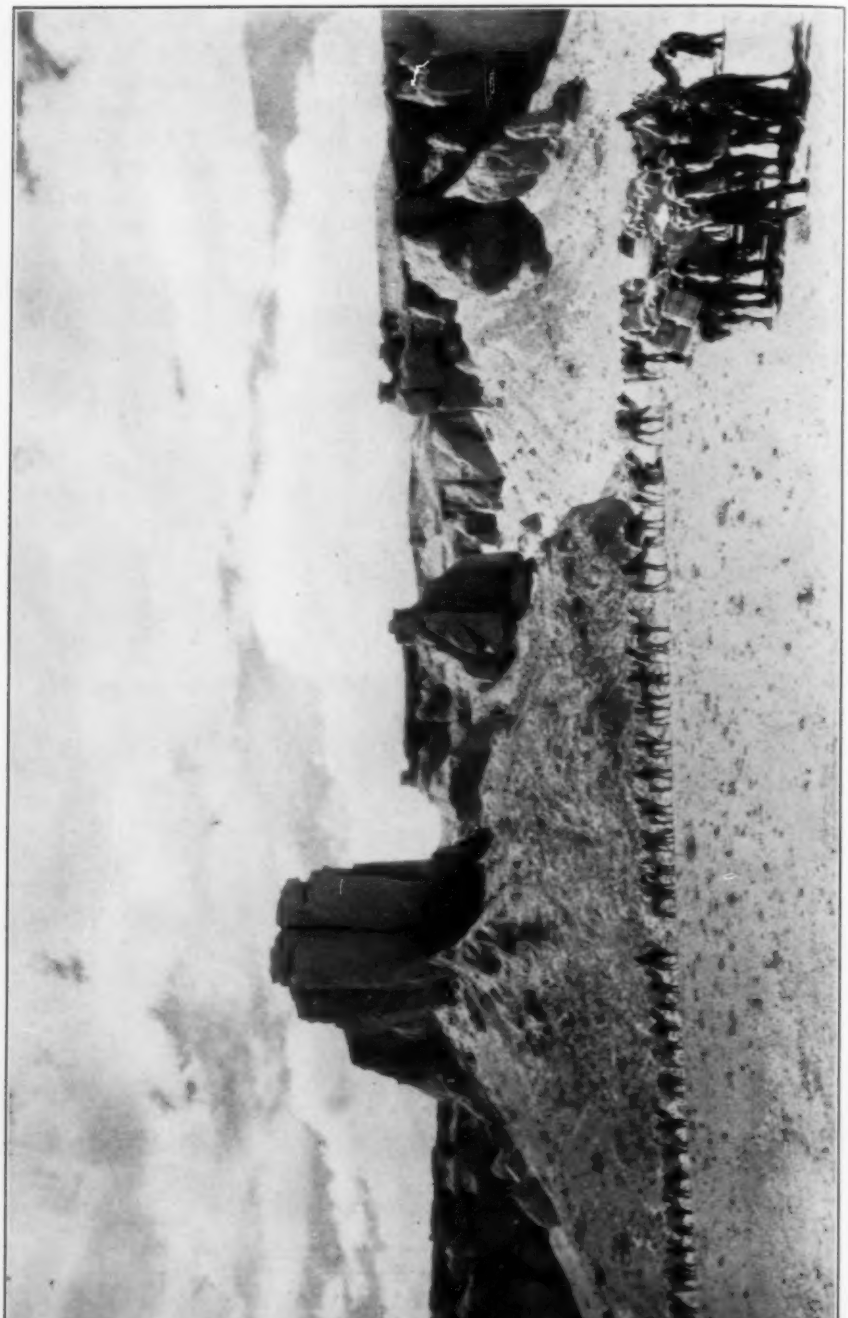
THE discovery of dinosaur eggs in Mongolia by the Third Asiatic Expedition of the American Museum of Natural History seemed to capture the imagination of the world and jokes about the price of ancient dinosaur eggs per dozen became every man's pleasantry. But the discovery of six imperfectly preserved fossil skulls of small mammals in the very same beds that yielded the dinosaur eggs was an event of exceptional importance only to the very few. Undoubtedly the most far-reaching result of the entire expedition has been the opening up of the geological record of a new world to geologists, but on the paleontological side of the expedition the Cretaceous mammal skulls are perhaps the most valuable fossils so far discovered.

The swarming dinosaurs of the Cretaceous age in Mongolia probably paid little attention to the "wee timorous beasties" with pointed snouts and furry coats that scampered around under their feet. With no one to warn them of the dangers of letting in a horde of immigrants that would eventually crowd them off the earth, the dinosaurs went

Photograph by American Museum of Natural History

FIG. 1. A "MISSING LINK"

FROM THE CRETACEOUS AGE OF MONGOLIA. WALTER GRANGER HOLDING ONE OF THE SIX PRICELESS SKULLS OF PLACENTAL MAMMALS OF THE DINOSAUR AGE FOUND BY HIM NEAR THE FLAMING CLIFFS AT SHABARAKH USU IN THE GOBI DESERT.



Photograph by American Museum of Natural History

PLATE I. CAMEL CARAVAN OF ONE HUNDRED AND TWENTY-FIVE CAMELS

AT THE BASE OF THE FLAMING CLIFFS AT SHABARAKH USU.

Photograph by American Museum of Natural History

PLATE II. ONE OF THE SANDSTONE CLIFFS AT SHABARAKH USU

on playing the game of life in the good old way and the immigrants did the same. For many hundreds of thousands of years the dinosaurs muddled through, but near the close of the Cretaceous age their doom was sealed and they disappeared from the earth in Mongolia as well as elsewhere. Thus the mighty were put down and the meek inherited the earth.

Numerous reasons have been alleged for this momentous event. Some have suggested that the little mammals broke into the dinosaurs' eggs and ate the contents. Others hold that in the long run the mammals came through because of their superior equipment for resisting severe changes in temperature; because of their improved locomotor apparatus, better brains and far less wasteful methods of reproduction. Be that as it may, the Cretaceous mammal skulls discovered by Walter Granger and his party at the Flaming Cliffs at Shabarakh Usu in the Gobi Desert have proved to be veritable missing links in the story of mammalian evolution. As might have been expected from previous evidence, the placental, or higher mammalian stock, even in Cretaceous times had already split up into various distinct lines. Hence it is not surprising that even in the five Cretaceous placental mammal skulls found in one locality in Mongolia we have representatives of four genera and two distinct families. The more insectivorous-like forms (Fig. 2, above) in some ways suggest the tenrecs or centetoid insectivores of Madagascar, but both their skull characters and their dentition are definitely less specialized than in their modern relatives. The members of the second family (Fig. 2, below) are distinctly more carnivorous in the general form of the skull and dentition and they combine characters of the carnivorous-insectivorous marsupials with others seen among the earliest creodonts or primitive placental carnivores of the Eocene age of North America. In both families the braincase is distinctly smaller than in modern insectivores or marsupials of the same size.

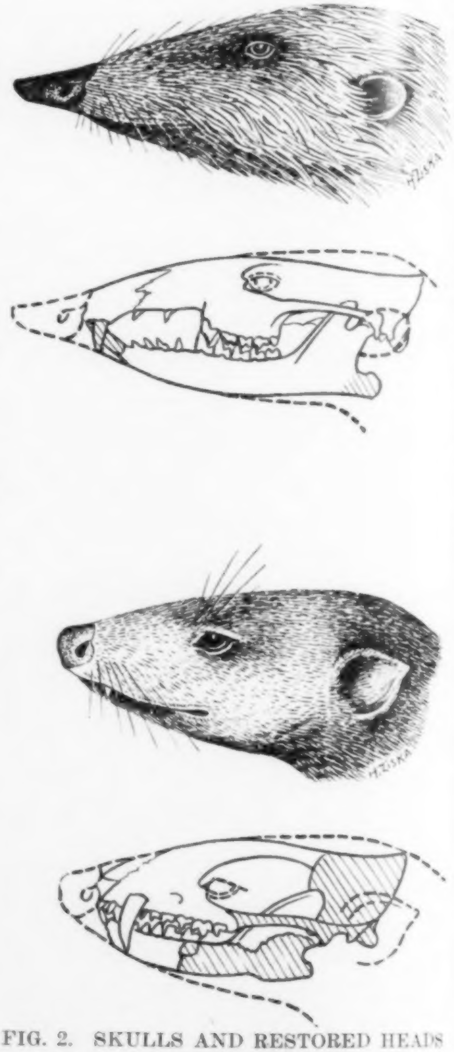
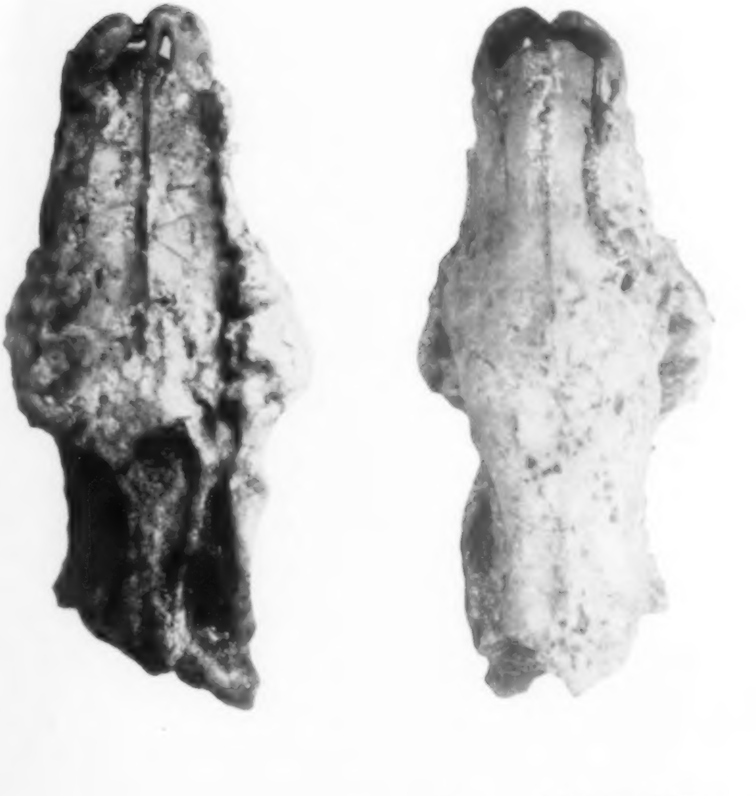


FIG. 2. SKULLS AND RESTORED HEADS OF THE MONGOLIAN CRETACEOUS PLACENTAL MAMMALS

NATURAL SIZE. ABOVE, THE "INSECTIVORE" (*Zalambdalestes lechei*). BELOW, THE "LITTLE CARNIVORE" (*Deltatheridium pretrituberculare*).



Prepared and photographed by Albert Thomson

FIG. 3. THE "LITTLE CARNIVORE" SKULL (*DELTATHERIDIUM*)
ABOUT THREE TIMES NATURAL SIZE.

Prepared and photographed by Albert Thomson

FIG. 4. ANOTHER OF THE "LITTLE CARNIVORES," PALATE AND LOWER JAW
ABOUT THREE TIMES NATURAL SIZE.

Huxley, Henry Fairfield Osborn and other paleontologists had already inferred that the remote ancestors of the higher or placental mammals in Cretaceous times were small forms of insectivorous-carnivorous habit, but prior to the Mongolian find the Cretaceous forerunners of the swarming placental mammals of early Eocene times were practically unknown except by a few scattered teeth from the Upper Cretaceous of North America of very doubtful affinities. After these priceless skulls had been very skilfully freed from the matrix by Albert Thomson, of the American Museum's technical staff, Drs. Andrews, Osborn and Matthew generously assigned them for study and description to the present writer, who in turn invited Dr. George G. Simpson, of Yale University, to collaborate in this study on account of his thorough knowledge of the Cretaceous and Jurassic mammal teeth secured long ago by Professor Marsh. Our observations, published in the American Museum Novitates and in the *American Journal of Physical Anthropology,* supply the evidence for the conclusion that even in the Lower Cretaceous the mammals as a class were already far from the beginning of their career and had already separated into Marsupials and Placentals, as well as an older side branch called Multituberculates. Secondly, the Mongolian skulls tend to confirm the view of Huxley and Osborn already noted, that the remote ancestors of the higher or placental mammals were insectivorous-carnivorous in habit, since the teeth in these fossils present significant resemblances to those of existing insectivores.

Another expectation or prophecy that these invaluable specimens support relates to an early stage in the evolution of the famous "tritubercular" type of molar tooth. Cope, Osborn, Matthew and others have produced cumulative evidence for the view that even the most diversified types of upper molar teeth among the later placental mammals may all be traced backward along gradually converging lines to a central type, a triangular form with three principal cusps, the apex of the triangle being on the inner or palatal side of the upper molars. This great generalization, one of the best established in the whole field of vertebrate paleontology, has unfortunately been obscured in the minds of many writers on human dental evolution by the more difficult question of the remote origin of the tritubercular type itself. Cope and Osborn held that the triangle in the primitive mammalian molars in turn arose from the folding up of a triad of cusps that were originally in a straight line (Fig. 7, I), in such a way that in the upper molars the larger central cusp shifted to the inner side of the tooth. Moreover, Osborn held that in the premolar teeth the original main cusp remained on the outer side of the tooth. Thus according to this view, the premolars and molars were essentially different as regards the origin of their crown pattern, no matter how much they might come to resemble each other in the later course of evolution.

Wortman, Gidley and the present writer, on the other hand, maintained that there had been no such shifting of the main original cusp in opposite directions in the premolars and molars, but that the low cusp on the inner side of the upper molars was not the displaced "original tip" or first cusp but, just as in the premolars, it was a spur or inward growth from the base of the crown, the original cusp remaining either in the center or near the outer side of the tooth (Fig. 7, II). According to the present writer's theory there should once have been a stage in which the two outer cusps of the triangle were not yet separated from each other, and in which the

Prepared and photographed by Albert Thomson

FIG. 5. THE "LITTLE INSECTIVORE" SKULL (*ZALAMBDALESTES LECHEI*)

FIG. 6. DIVERGENT EVOLUTION OF UPPER MOLARS INTO SHEARING AND GRINDING TYPES

IN THE "LITTLE CARNIVORE" OF THE MONGOLIAN CRETACEOUS (No. 2) THE UPPER MOLARS ARE OF THE "PRETRITUBERCULAR" TYPE. THE SHEARING SERIES AT THE LEFT IS BASED ON SUCCESSIVE STRUCTURAL STAGES IN THE SECTORIAL UPPER MOLAR OF EXTINCT CARNIVORES OF THE HYAENODONT FAMILY. AFTER OSBORN, MATTHEW AND GREGORY. THE GRINDING SERIES AT THE RIGHT IS BASED CHIEFLY ON SUCCESSIVE STRUCTURAL STAGES IN THE GRINDING UPPER MOLAR OF THE HORSE (10, 11, 12).

inner cusp had the appearance of a low process or heel. Exactly such a stage is supplied by the molars of several of the Cretaceous mammal skulls from Mongolia (Fig. 6, 2).

With regard to the lower molars, the adherents of both these rival interpretations were in agreement that, whatever the remote origin of the lower molars may have been, there was an early stage in which the primitive lower molar crown consisted of two distinct parts, the front part comprising a triangle of three sharp cusps, the back part consist-

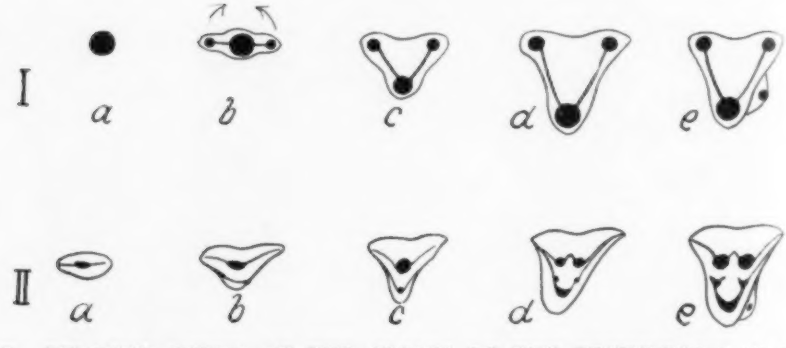


FIG. 7. OPPOSING VIEWS OF THE ORIGIN OF THE TRITUBERCULAR UPPER MOLAR OF PRIMITIVE PLACENTAL MAMMALS

I. THE COPE-OSBORN THEORY. II. THE AUTHOR'S THEORY; *a, b, c, d, e*, SUCCESSIVE STAGES.

ing of a low projection or heel. In the later mammals the back part or heel is very often wider transversely than the front part or triangle, and when this is so, the large cusp on the outer side of the heel of the lower molar fits between and on the inner side of the two well-separated outer cusps of the upper molar. It was predicted by the present writer that the "pre-tritubercular" molars of placental mammals should have the heel of the lower molars narrow transversely and the main outer cusps of the upper molars not yet separated from each other. Several of the Mongolian Cretaceous mammals remain in this stage of evolution and thus tend to fulfil the prophecy, while others have already advanced toward the more typical later stage of evolution with nearly separate outer cusps in the upper molars and relatively wider heels on the lower molars. This indicates that still earlier stages of molar evolution must be sought in formations older than the Djadokhta formation (Cretaceous) of Mongolia. And these earlier stages, long known from the Upper Jurassic of Wyoming and Great Britain and long since described by Owen, Osborn and Marsh, are

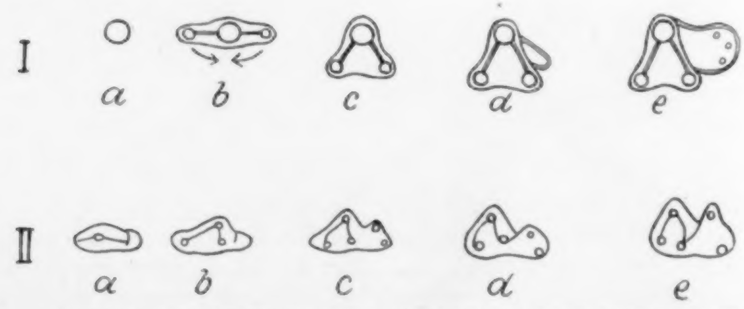


FIG. 8. RIVAL THEORIES OF THE ORIGIN OF THE TRITUBERCULAR LOWER MOLAR

I. THE COPE-OSBORN THEORY. II. THE AUTHOR'S THEORY.

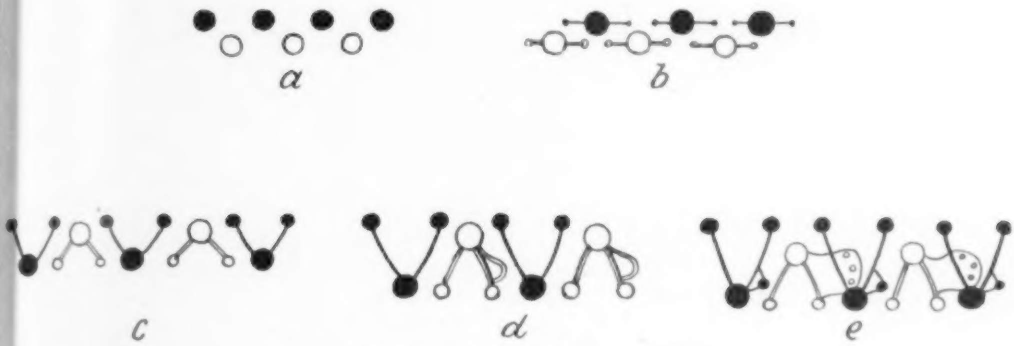


FIG. 9. THE COPE-OSBORN THEORY

OF THE EVOLUTION OF OCCLUSION OR INTERLOCKING RELATIONS BETWEEN THE UPPER MOLARS (BLACK DOTS) AND THE LOWER MOLARS (WHITE DOTS).

now being critically and very successfully restudied by Dr. G. G. Simpson, of Yale University.

The Mongolian placental mammal skulls thus tend to bridge the gap in time and in evolutionary stage between the known Jurassic mammals on the one hand and the Eocene mammals on the other. To this extent therefore they may be regarded as "missing links" in the evolutionary pedigree of the later mammals, including man.

FIG. 10. AUTHOR'S THEORY

OF THE EVOLUTION OF OCCLUSAL RELATIONS OF UPPER AND LOWER TEETH. SUCCESSIVE STAGES OF COMPLICATION SEEN FROM LEFT TO RIGHT.

BOTANICAL EXPLORATIONS IN THE ROCKY MOUNTAINS

By Professor J. E. KIRKWOOD

STATE UNIVERSITY OF MONTANA

THE Flathead River drains the western slope of the Montana Rockies between latitudes 47° 20′ and 49°. Above Flathead Lake it divides into three branches, the North, Middle and South forks. The North Fork lies along the western side of Glacier National Park and has been easily accessible by wagon road for many years. The Middle Fork is followed through much of its course by the Great Northern Railway. The South Fork, however, with its numerous tributaries, traverses an isolated and little known region, a remote wilderness, approximately fifteen hundred square miles in extent. The stream flows in a northwesterly direction over one hundred and fifty miles and finally swings westward and joins the other branches near Columbia Falls. It is fed from the east by streams rising under the very crest of the Continental Divide and from the west by branches from the Swan Range. The floor of the valley lies mostly above 3,500 feet but peaks along the limiting water sheds rise to altitudes of 9,000 feet, or more. The topography is rugged and picturesque, rising in towering cliffs or precipitous slopes of stratified rocks of ancient, mostly proterozoic age.

There is no record of which the writer is aware of any botanical collections or observations of this valley except about its mouth, where a few collections have been made. The whole interior valley is entirely virgin territory, which induced the author to spend some time in the

MAP OF MONTANA

AREA COVERED OUTLINED AND SHADED. BY PERMISSION OF RAND, MCNALLY AND CO.

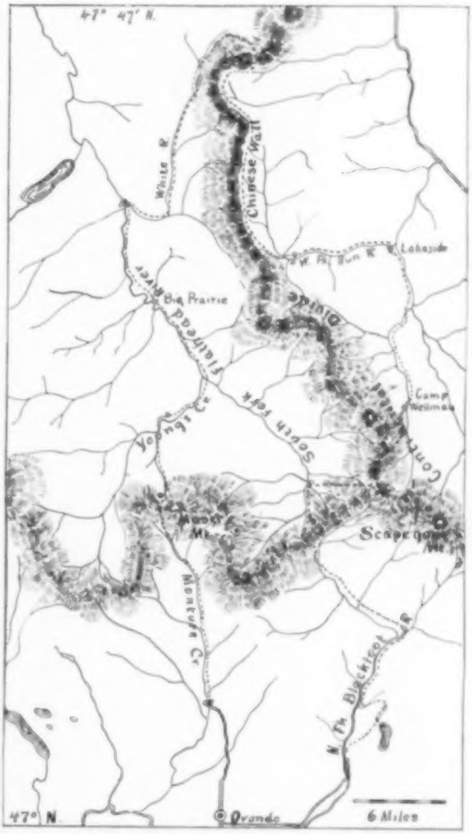
summer of 1925 in the effort to make a brief reconnaissance of its flora. Although only about seventeen days were available and the trip somewhat hurried, a fair impression was obtained of the vegetation in its composition and distribution. The season was far advanced, but a representative collection was made, which with notes and photographs will form a permanent record of the observations.

Combining geological and botanical objectives, our party included President C. H. Clapp and Professor J. H. Bradley, geologists, and Mr. J. H. Ramskill and the writer, representing the botanical interests, all of the State University of Montana. Besides these were Mr. Burr Lennes, attracted by the recreational opportunity, Joseph Murphy, Virgil Woods and Gilbert Muchmore, packers, and William Burns, cook.

Supplies and equipment having been shipped from Missoula by truck some days previously we left town on the morning of August 23. The first lap of our journey took us by auto over a good road along the Blackfoot River, a distance of nearly sixty miles, to the village of Ovando, situated in a broad basin marked by numerous small drumlins and moraines of glacial gravels. At this place the Weather Bureau records show that the last killing frost of the season occurs in July and the first in August. The altitude is 4,100 feet.

From Ovando we proceeded north to a point on Monture Creek, where our packers had assembled the outfit, consisting of twenty-two horses and the usual camping paraphernalia and supplies. Here we left the auto for the saddle. The packs were made up and preparations completed for an early start the next morning.

Monture Canyon is the main southern gateway into the South Fork country. It heads upon the divide separating the waters of the Flathead and the Black-



MAP OF AREA TRAVERSED ON THE TRIP

ROUTE INDICATED OVER MAIN RANGE OF THE ROCKIES AND PARTS OF THE COLUMBIA AND MISSOURI DRAINAGE.

foot. Our course lay up this canyon toward high summits visible from far out in the Blackfoot valley.

We broke camp in the morning under a dull and leaden sky. Rain had fallen during the night and threatened all day. Clouds hung low and the neighboring crests shone with the gleam of newly fallen snow. The wind blew chill and raw and the nodding flowers along the trail seemed out of place in the wintry scene.

On leaving the plain the first species met are the widely distributed yellow

SOUTH FORK OF THE FLATHEAD AT BIG PRAIRIE

NEAR THE SUMMIT OF THE DISTANT PEAK IS SHOWN A BED OF LIMESTONE SANDWICHED IN THE SPOKANE FORMATION.

pine (*P. ponderosa*) and the Douglas spruce (*Pseudotsuga taxifolia*) which in all this region form the marginal forest growth at the tension line between woodland and prairie. On steep slopes, however, it is only a fringe and soon becomes mixed with and then replaced by the lodgepole (*Pinus contorta*), sometimes with a liberal addition of western larch (*Larix occidentalis*). Engelmann spruce (*Picea engelmanni*) and the sub-alpine fir (*Abies lasiocarpa*) begin to appear in the narrow gulches and grow increasingly abundant until they become dominant in many places above 5,000 feet, where the white bark pine (*P. albicaulis*) mingles with them in increasing numbers up to the limit of tree growth.

Gradually the stream at our left dwindled to a mere brook and divided into numerous feeders emerging from narrow gulches slanting into the main canyon. We were nearing the pass. Ahead of us loomed walls of crumbling shale, their deep strata of red and green argillite showing through the scant vegetation. The Spokane formation with its strongly ripple-marked deposits is conspicuous through all these mountains. At last we topped the summit at 6,600 feet and began the descent into the Flathead drainage. The trail dropped rapidly now to Hahn Creek, a small stream, at a point on which a mile or more from the pass we had agreed to make camp. We were now in the green timber and along the stream below us appeared frequent open grassy glades, inviting after the first day's ride of twenty miles. The sun was now shining and the sky clear as we pulled into Bear Slide Camp at mid-afternoon.

The sun set early behind a high ridge and with the shadows a chill settled in the canyon and before morning grew into a heavy hoarfrost. "Virg" and "Gil" pitched the tepee and before its entrance built a roaring fire, around which we sat and talked while the thin crescent of the new moon sank to early rest behind the hills. Finally we sought our blankets in the firelight's fading glow and were soon lost to sense of camp and trail.

With the first gray streaks of dawn the men were astir, the cook's fire was crackling, bacon was sizzling and in an incredibly short space the call, "Come and get it," rang out. Some whose more sensitive ears had caught the first sounds of the day's business had washed in the ice-cold stream and dressed with promptitude and now lined up to a breakfast of oatmeal, bacon and eggs and potatoes with steaming hot coffee, while the more tardy members made hurried dashes to complete the morning's toilet and appear at the board before it was too late.

It remained now to roll our bedding and prepare for the day's march. Everything must again be compactly stowed and prepared for the packing. Ordinarily the horses have been rounded up before breakfast and now while the cook is washing the dishes and putting his stuff away, horses are being saddled, the tents come down and we are again on the trail before the sun has fairly risen on the landscape. On this occasion Mr. Ramskill and the writer elected to remain behind and work the local vegetation while the rest of the party proceeded to the next camp on Young's Creek, some seven miles below.

Moser Mountain rises abruptly from its base on Hahn Creek to an altitude of 8,530 feet. Much of its slope stands at an angle of forty-five degrees, with here and there precipitous walls or more gentle acclivities. Several places on its western face are bared by snow slides. One of these rises from our camp site about two hundred yards wide to a distance of a quarter of a mile or more from which every vestige of forest has been swept away. The deep, accumulated snows, loosened as thawing begins, break loose and rush down with tre-

FOLLOWING THE CONTINENTAL DIVIDE
THE PACK TRAIN ON BENCHMARK MOUNTAIN.

mendous force. The foot of such slides is usually marked by a tangled mass of splintered, broken trees intermingled with rocks and earth. Here, however, the debris has disappeared by fire or decay and the frequent recurrence of the avalanches keeps the forest from gaining a foothold. Upon ascending over this bare slope it seemed remarkable that snows could accumulate upon it, so steep and insecure was the footing which we experienced. Short sod-forming grasses and sedges alternating with patches of bare rock or low thickets of alder (*Alnus sinuata*) constituted the ground cover. Occasional gullies occupied by trickling streams are fringed with species of *Saxifraga, Arnica, Senecio, Campanula* and *Osmorrhiza* in good flowering condition at 7,000 feet. Above the slide, the slope bears a sparse forest with meager undergrowth, so that little difficulty was experienced in passing through. Here as elsewhere in the region at similar altitudes, the open forest is carpeted with a sod of the wood rush (*Juncoides glabratum*). Below 7,000 feet, on a warm and dry exposure, yellow pine, Douglas spruce, Rocky Mountain juniper (*Juniperus scopulorum*) and patches of creeping juniper (*J. Sabina*) were found. At all elevations, more or less, but especially at higher points and on the very summit, we found the dwarf juniper (*J. communis*) in spreading procumbent shrubs. The forest of the upper slopes is almost pure white bark pine and reaches to within one hundred yards of the summit. Here massive rocks tumbled one upon another bear only a thin crust of lichens or in a few favored places a sod of *Saxifraga austromontana*. The top is a narrow space, mostly of smooth rock or shingle, but a pile of coarse rock fragments yielded specimens of *Rubus* and *Ribes* a foot in height, their tops beaten back to the level of the surrounding stones.

What stirred us most, however, as we gained the summit and looked beyond into a broad basin two or three hundred feet below, with a northeastern exposure, was a fine little stand of Lyall's larch (*Larix Lyallii*), that rare and interesting species which is seldom found below 8,000 feet in this latitude and which, while partial to sheltered spots, still ascends to greater altitudes than any other of our forest trees.

Our time was short, but we paused to enjoy the magnificent panorama spread out before us. The rugged grandeur of the wilderness in lofty peaks and deep dark canyons extended far toward all points of the compass; the Swan Range to the west and beyond them a glimpse of the Mission Mountains, to the east not so far away the Continental Divide rose as a huge barrier with its high points of Sugarloaf and Scapegoat, and far away to the north in the blue haze of the horizon peak followed peak until the serrated skyline was lost in the distance. Regretfully we turned our backs upon the scene and began the descent. Considerable care had to be exercised in avoiding dangerous footing and in finding our way around the precipitous walls, less evident in the downward than in the upward progress.

The trail down Hahn Creek leads through a heavy forest of pine, spruce and fir. The stream flows through a narrow gulch with high and steep slopes on either side enhancing the deep shade, and after two hours riding through this defile we were glad to emerge into the wider valley of Young's Creek, a stream about fifty feet in width at the ford where the water came to the horses' knees. The bottom at this point, about half a mile in width, is scantily covered with lodgepole pine or treeless, except for the thicket of alders, willows and

FOX'S CABIN IN THE SOUTH FORK VALLEY

AN EARTH ROOF BEARING A CROP OF PLANTS. TREES ARE LODGEPOLE PINE (*Pinus contorta*).

THE CAMP AT BIG PRAIRIE

FOREST OF YELLOW PINE AND WESTERN LARCH IN THE BACKGROUND.

cottonwood that fringes the creek. A mile or two beyond the ford brought us to the camp in a grove beside the stream.

The day was far spent, but we still had an hour or more before dinner and plenty of work to fill it. The collections had to be put away and the field notes written up. Often this work carried over into the candle light. Every day brought its additions and the accumulation of material in the presses required attention. Most of our collections were made along the trail from early morning until mid-afternoon or later, with an average march of fifteen miles a day. As the trails traverse varying soil conditions, exposures and altitudes the record of the plant life as seen on either hand affords a sort of huge belt transect crossing mountain ranges and valleys. Considering the large area of the new territory and the short time available a passing view of the vegetation was preferred to a more intensive study of a small locality.

The next stage of the journey took us twelve miles to Big Prairie. Big Prairie is a treeless flat several square miles in extent lying in the broad valley of the river. Here and there groves of yellow pine and the lodgepole forest encroach upon its margins. Along the river are found western larch, Engelmann spruce and Rocky Mountain juniper. The prairie, with its bunch grass, sagebrush and shrubby cinquefoil (*Dasiphora fruticosa*), is distinctly arid transition, while the Canadian zone is represented by the lodgepole and spruce. The snowberry (*Symphoricarpos racemosa*) and *Rhamnus alnifolia* are plentifully represented. The floor of the valley breaks

abruptly in steep slopes which rise in rugged walls to elevations of 7,000 feet or more, heavily wooded from the base. The east and north exposures are especially favored, where lichens (*Peltigera* and *Cladonias*) abound in the forest duff and rattlesnake plantain (*Peramium menziesii*) and *Pedicularis racemosa* are plentiful.

Like all streams of this mountain region the South Fork of the Flathead pursues its way over rock ledges, sand bars and beds of gravel and boulders. At Big Prairie it is sixty to one hundred feet in width, shallow, but crystal clear in the deepest pools, abounding in beautiful trout. The black cottonwood (*Populus trichocarpa*) is the principal deciduous tree of the banks along with numerous shrubby willows. Thickets of cornel (*Cornus stolonifera*) are frequent. Herbaceous life along the gravel-strewn shore includes an onion (*Allium sibiricum*), low fireweed (*Chamaenerion subdentatum*), *Galium boreale* and mint (*Mentha canadensis*) in vigorous flowering condition.

At Big Prairie, according to previous arrangement, the party divided. The botanical contingent, with two packers, Murphy and Muchmore, and ten horses proceeded on a more extended trip, while the geologists elected to explore for fossils the Devonian and Mississippian deposits of the neighborhood. Accordingly after a couple of days at Big Prairie we pulled out northward, with the mouth of White River as our first objective. White River enters the South Fork from the east, but most of its course is parallel with the other stream flowing southward in the heart of a great syncline until, about seven miles from its mouth, it swings directly west to a junction with the South Fork. The white limestone gravels of its broad bed are conspicuous and when viewed from a high lookout are traced with ease for a great distance.

One of the notable plants of the broad gravel bars and sand flats were the frequent mats of *Dryas octopetala*, now mostly past its fruiting stage. Meadows and swamp areas in this locality yielded the best collections of *Aster, Erigeron, Agoseris, Heracleum, Angelica* and other genera. Here also the flats, treeless or with occasional yellow or lodgepole pines, were common.

The morning of the 29th found us early in the saddle with thirty miles to go to the evening's camp. Our trail followed White River to its source. In places of precarious and even dangerous footing we found it safer to lead than to ride our horses. For many miles the trail led through a burned forest with its usual scene of devastation, but as we gained elevation we had an unobstructed view of the rugged landscape. On our right the land swept up in gradual ascent to the Continental Divide and to our left fell away to the bed of White River. For considerable distance it was a river in name only, disappearing completely under its gravels and reappearing suddenly in full view. Later our trail emerged on a flat area known as the "Meadows," where rather scant grasses and sedges were cut by dry water-courses fringed by low willows and dwarf birch (*Betula glandulosa*). The river had now dwindled to a mere brook.

So far our ascent had been easy and gradual, but suddenly the trail left the stream and led us eastward. By a series of "switchbacks" or zigzag turns we began to climb the divide and for an hour or more ascended steadily a rather stiff grade. The lodgepole disappeared and the whitebark pine became general in its orchard-like formation. Suddenly as we topped a spur we looked over into a grove of Lyall's larch and knew that we were not far from 8,000 feet. A few rods farther and we stood on the Continental Divide. The aneroid indicated 7,900 feet. We now dropped rapidly

WESTERN YELLOW PINE

A FAMILIAR STAND ON SOUTHERN SLOPES AND FOREST-PRAIRIE MARGINS IN THE REGION.

on to the Missouri drainage at the head of Moose Creek, a tributary of the Sun River.

Our view of the main range of the Rockies from the White River canyon had presented no features of special interest. Immediately, however, on gaining the crest a thrilling view was unfolded to our gaze. The eastern face of the divide dropped perpendicularly a thousand feet and reached away southward mile upon mile. These huge cliffs of limestone, known as the "Chinese Wall," are the edges of strata dipping to the valley of White River. They vary in alternate promontories and shallow bays, the former rising as peaks along the crest. It was a magnificent view which gained in impressiveness as we made our way around the end of the wall and down under its broadening shadow at the close of the day.

It was sundown at four o'clock, but the next morning the sun rose over the rim of the world at six and looked straight into the door of our tent, a unique experience in the mountains where camp is usually made in a hollow, where shadows lie late in the morning and come early in the evening. The day was spent here in working over the old collections and adding new. Our climb to the top of the divide at one of the lower gaps was rewarded by one of the finest views of the trip. Here at somewhat over 8,000 feet there spread out before us a wild expanse of canyons and peaks as far as the eye could reach.

A burned forest covers the western slope almost to the crest of the ridge. The wind-swept top of the divide bore only dwarf vegetation represented by draba (*Draba andina*) closely nestled among the loose stones and of much the same color. *Arctostaphylos alpina* spread in close mats over the rock. In the lee of the top, on the east side, golden buckwheat (*Eriogonum Piperi*) was in full bloom, also columbine (*Aquilegia flavescens*), cinquefoil (*Potentilla perdissecta*), *Senecio Purshianus* and *Festuca rubra*. On the lower ground the dominant almost sod-like association of bear grass prevailed. In wet places clumps of *Erigeron salsuginosus* and *Senecio triangularis* were frequent and one of the most abundant plants was the beautiful gentian (*Gentiana calycosa*), opening fully only in the bright sunlight. Engelmann spruce and sub-alpine fir were almost the only trees.

The next morning saw us again mounted. Our way now was not defined by trail but, guided by landmarks, we hoped to make our way to the west branch of the South Fork of Sun River. Keeping close under the wall between the forest and the cliff progress was made without much difficulty. But the country grew rougher as we advanced and became a succession of ridges and basins at the heads of various small streams.

Here one of the most interesting events of the trip transpired. We were now in the Sun River Game Reserve and were alert for a sight of the big game, signs of which had been visible for days past. Suddenly the packers signalled that elk were near. Stopping the pack train and dismounting we cautiously made a short detour to the left. We succeeded in getting within a stone's throw of some of the band before they took fright. Several of them stopped and gazed at us. The country having been burned over there was little obstruction to vision and we stood fascinated by the wild and beautiful scene before us. As the herd moved off across a wide canyon beyond we counted well up towards forty, and others that we could hear but not see left little doubt that there were fifty or more. The mating season was drawing on and the bulls were in full horn. Their calls rang bugle-like across the wide canyons. There are said to be about 4,000 elk in this reserve, and they

ACROSS THE VALLEY OF WHITE RIVER

LOOKING WEST FROM THE CONTINENTAL DIVIDE. PICTURE TAKEN FROM AN ALTITUDE OF 8,000 FEET.

are multiplying so rapidly as to be an encumbrance to the range. Consequently, the reserve was thrown open recently for a limited amount of hunting.

We made our way back to the horses in high spirits over this experience. But we were still further rewarded by the view of mountain goats along a ledge of the wall. They paralleled our course for some distance and then disappeared.

Finally we topped another high ridge and, turning our backs on the wall, descended one of the branches of Red Butte Creek, followed it to the forks and ascended the other branch toward a saddle which we had had in view for some time. Pulling up this about forty-five degree slope was the steepest ascent we experienced.

Dropping down on to Indian Creek along an old, abandoned trail, our way led through a burn of ten to fifteen years ago. The roots of the dead trees were rotting and thousands of trunks were thrown in all directions. We had literally to hew our way through and were hours making a few miles. A burn in this condition is always a dangerous place and that night in our safe camp on the West Fork a storm swept over and we were very thankful that we had got through. The vicissitudes of a steep and dangerous trail and the labor of threading through a maze of fallen timber left us no time here for collecting, so we decided to remain over a day and work the locality, which proved rather fertile.

The West Fork is more prolific in the operations of beavers than any other stream in the writer's experience. It is a shallow creek of twenty to forty feet in width, not too rapid and with low banks. Such conditions make building easy and a dam of four or five feet will sometimes impound water enough to cover several acres. Tall cottonwoods up to two feet in diameter are felled by these industrious rodents and various

other woody growth along the banks is requisitioned and cut up for their purposes.

Such beaver ponds induce certain changes in the vegetation, first in a retrogressive, then in a progressive succession. The flooding of an area soon kills the trees and other vegetation upon it. Eventually these come down, floods and freshets sweep sand and silt into the pond, grasses and sedges spring up about its margins and after a varying lapse of years a meadow results. The meadow is not the final stage of the succession but the most obvious one. Willows, birch and cornel come in and spruce may follow as a climax. Or the silting process, if rapid, may so change the quality of the soil that drier conditions may intervene and change the character of the succession. Seldom if ever in this progress does peat moss appear. A sedge (*Carex rostrata*) is usually the dominant member in the early invasion of the ponds. In many places it is practically pure. Or grasses like *Alopecurus* and *Beckmannia* appear, and later, as the soil accumulates, *Panicularia elata*, *Juncus xiphoides*, *J. confusus*, or *Carex Mertensii* and other herbaceous plants varying with the location but not especially characteristic of the succession.

Another day brought us to Lakeside after a short ride of ten miles. An unoccupied cabin, a deserted camp and a corral in a grove of lodgepole pines at the border of a small prairie is all that is visible of Lakeside where the West Fork joins the South Fork. Our trail thither followed the stream at a little distance above it and along the foot of Prairie Reef a largely treeless elevation facing the south. The point of chief interest here was the aspen thickets scattered over the landscape. The trees were slender saplings twelve to fifteen feet in

ASPEN (*POPULUS TREMULOIDES*)

ON THE SUN RIVER GAME RESERVE. BRANCHES BROWSED TO UNIFORM HEIGHT OF 7 OR 8 FEET BY ELK IN WINTER.

THE "CHINESE WALL"

EAST FACE OF CONTINENTAL DIVIDE. TOP OF THE RIDGE ABOUT 8,000 FEET. FROM THE LEVEL OF THE FOREST TO THE TOP OF THE RIDGE IS ABOUT 1,500 FEET. FOREST MAINLY SUB-ALPINE FIR.

THE "CHINESE WALL."

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height in island-like groves influenced in their occurrence by the presence of springs or seepage. They presented a very striking appearance as if pruned below to a uniform height of about seven or eight feet from the ground, due to the winter browsing of the elk. Everywhere within sight this feature presented itself with characteristic uniformity. Occasional patches of sage (*Artemisia tridentata*) appeared, indicative of the dry conditions, and along this trail we found the first specimens of the silver berry (*Elaeagnus argentea*). The coniferous growth in favorable spots consisted largely of lodgepole and some yellow pine, but on the bluffs above us appeared a scattering growth of limber pine (*P. flexilis*).

Turning sharply here we proceeded southward, ascending the South Fork of the North Fork of Sun River. This stream, somewhat greater in volume than the West Fork, runs almost parallel for much of its course with the Continental Divide and at a distance of two to four miles. Our altitude at Lakeside was about 5,000 feet, but gradually rose to near 5,800, where we camped at Wellman late in the afternoon, having traveled some fifteen miles. This trail passes alternately through areas of green and burned timber, lodgepole mainly in both cases. Here over considerable areas the mature lodgepole pine was associated with a dominant grass (*Calamagrostis scribneri*) as a ground cover. Along the streams cottonwood (*Populus angustifolia*) and willows (*Salix McCalliana*) (*S. discolor*) predominate. In its mature form this cottonwood very closely resembles the black cottonwood (*Populus trichocarpa*) of the Pacific slope, but the leaves are narrower.

After a night at Camp Wellman we continued for a mile or two along the stream and then swung to the right up one of the spurs toward the Divide. Just before reaching the summit and at an altitude of 7,500 feet or more we came upon the white Rhododendron (*Rhododendron albiflorum*). This was a decided extension of range for this shrub, as it had not hitherto been reported in Montana except from one station in the Mission Mountains (Mt. MacDonald), although previously found by the writer in various places in the Bitter Root Range.

The trail here follows the Continental Divide for some miles until it comes to the three-way ridge which separates the waters of Sun River on the east and those of the Blackfoot and Flathead on the west. Soon after reaching the top we came unexpectedly upon the party we had left at Big Prairie. We immediately joined forces and, making our way along the crest, crossed the summit of Benchmark Mountain at 8,522 feet, and descended on the Sun River side a few hundred feet to a grove of trees near a tiny stream, where we made camp. Above us towered the precipitous wall of the northwestern shoulder of Scapegoat Mountain.

Again we crossed the Divide and descended into the South Fork valley to Willow Creek. Most of the way led through green forests, mostly of lodgepole pine, until we emerged at the bottom upon an open grassy flat with some sage and shrubby cinquefoil and occasional groves of pine. Here we laid over a day, giving time for some observations and collections.

Small streams traverse this basin on the way to the South Fork some miles below. Here we have one of the most extensive areas affected by beaver workings. This may cover a total of a square mile or more in extent and exhibits early and late phases of the succession, standing water, the sedge phase, the willow and birch association, etc. Many acres are covered now with a uniform growth of willow, only two species observed (*Salix McCalliana, S. subcoerulea*) and

Birch (*B. glandulosa*) about five to six feet high. The animals are still industriously trying to reclaim their pond and are succeeding in throwing the water back again over much of the ground once lost to the vegetation. Where the ground is bare the coal-black soil of almost pure vegetable origin is exposed to view. Here again *Carex rostrata* is the dominant plant in the first invasion and covers a considerable area in a pure stand.

From here we turned again toward the Blackfoot Valley and took our way up Danaher Creek, keeping the bluffs on our left and the willow flats on the right. Danaher Mountain loomed before us, a rugged mass. We rose by insensible degrees, and reached the pass at the low elevation of 5,400 feet. So wide and flat is this remarkable pass that the first intimation that we had of having crossed the summit was in observing the reversed direction of the stream flow. Descending by stages as gradual as those by which we had ascended we came soon to the Dry Fork of the Blackfoot River. For miles the bed of this river is entirely dry, strewn with smooth stones and gravel, the stream flowing below the surface.

Camp was made on the North Fork of the Blackfoot a short distance below the falls. All day the sky had been dull and lowering and sprinkles of rain now fell at intervals. We had scarcely made camp safe for the night when it began to rain in earnest. It rained much during the night and at some place above us must have assumed the proportions of a cloudburst, for in the morning the stream, usually clear as crystal, now ran full, turbid and yellow. Here of course, on the last morning of the trip and under conditions least agreeable for such a circumstance, our usually well-behaved horses had taken the notion to strike out for parts unknown. The packers were early astir, but it was ten o'clock before the bunch were rounded up.

The trail from this point follows the river most of the way, although often forced up the mountain and around bluffs here and there with precarious footing in loose and sliding talus. Much of the way is through green forests that have escaped the ravages of fire. The big tamaracks and yellow pines again appear as on the Monture some distance to the west. Passing this belt we enter once more the agricultural country some seventeen miles from Ovando and our trip was virtually at an end.

We emerged abruptly upon the Kleinschmidt Flats. Winding in and out among the pines is an old wagon road. Autos were awaiting our arrival and as the need of the horses was now over, we transferred their loads to a truck and dismissed the packers. A hot supper and a night ride to Ovando closed the day. We had swung around a loop of nearly two hundred miles.

LAMARCK AND THE EVOLUTION THEORY

By Professor RALPH F. SHANER
UNIVERSITY OF ALBERTA

Few of the recent articles on evolution mention any name older than Darwin. Perhaps this is well: we have enough to regret in the present controversy. The omission is evidence, just the same, of a general belief that the modern evolution theory began with Darwin, and that all earlier writers possess only historical interest.

There is indeed a sharp distinction between the modern theory and those proposed before it. The line should be drawn, however, not when the "Origin of Species" appeared, but just fifty years earlier, when Lamarck published his "Zoological Philosophy."

Lamarck approached the evolution question near the close of a singularly fruitful scientific career. Up to the age of fifty, he occupied himself exclusively with botany. Then, in 1793, the Museum of Natural History in Paris was reorganized. Lamarck was transferred to an utterly new field and appointed "professor of zoology, insects, worms and microscopic animals." At a time of life when most scientists are content to glean the stubble of more fruitful years, Lamarck began the study of the least known part of the animal world. He determined the position and affinities of thousands of forms, improved the existing classification of Linnaeus and Cuvier and laid the foundation for invertebrate paleontology.

With the growth of his knowledge of vegetable and animal life, Lamarck reached the point when he could no longer harmonize the facts with the prevailing doctrine of the fixity of species. In spite of opposition and ridicule, he became an evolutionist. His beliefs are set forth in several works, but perhaps most fully in his "Zoological Philosophy," published in 1809. In this work Lamarck attacks the problem that Darwin attempted to solve a half century later.

The "Zoological Philosophy" is generally considered a classic work. Like most classics it is seldom read. For this the modern student can plead some excuse. The book contains considerable superfluous matter—at least when judged by modern standards—so much so that the reading of it in the original French is an exhausting undertaking for the average doctor of philosophy. In addition Lamarck's style of presentation belongs to a past era in scientific literature. For those who wish to know more of the book than the stock quotations afford, the language obstacle has been cleared away by an excellent and very readable translation made by Hugh Elliott.[1] The following abstract of Lamarck's argument, given as far as possible in extracts from his work, but rearranged in a modern order, will show the nature of his theory of evolution and its place in scientific thought. Since Elliot's translation is more accessible than the original and his rendering of Lamarck's words better than any I can offer, I will quote from the translation.

To begin with, Lamarck had a clear conception of the uniformitarian principle. He believed, as we do to-day, that all events in past world history can

[1] "Zoological Philosophy," by J. B. Lamarck; translated, with an introduction, by Hugh Elliot, Macmillan and Co. 1914.

be explained best as the result of the operation of present-day forces of nature. The prevailing view in Lamarck's time was very different. The school of Werner, then at the height of its popularity, solved all geological puzzles by an appeal to floods that might have staggered the imagination of the writers of Genesis, and by calling in a chemistry as fantastic as medieval alchemy. Quite as popular were the Catastrophists, who laid the destruction of fossil forms to great disasters which at one time overwhelmed the world, utterly destroying every living thing. Lamarck, however, took his stand with Hutton and Demarest, and postulated the uniformitarian principle as the foundation for his evolution theory.

> Every qualified observer [Lamarck writes] knows that nothing on the surface of the earth remains permanently in the same state (p. 45).
>
> Naturalists who did not perceive the changes undergone by most animals in the course of time tried to explain the facts connected with fossils, as well as the commotions known to have occurred in different parts of the earth's surface, by the supposition of a universal catastrophe which took place on our globe. . . .
>
> But why are we to assume without proof a universal catastrophe, when the better known procedure of nature suffices to account for all the facts which we can observe?
>
> Consider on one hand that in all nature's works nothing is done abruptly, but that she acts everywhere slowly and by successive stages; and on the other hand that the special or local causes of disorders, commotions, displacements, etc., can account for everything that we observe on the surface of the earth, while still remaining subject to nature's laws and general procedure . . . (p. 46).

Darwin warmly acknowledged that it was Lyell who taught him to look for the cause of past changes among causes for change in the present, and thus started him on the road that led to evolution. Under far less favorable conditions Lamarck attained a thorough grasp of the same principle, without which no evolution theory is possible.

With Lamarck it is especially necessary to distinguish his evolution theory in the narrower sense; *i.e.*, his concept of the fact or law of evolution, from the causes or factors which he thought brought about the process of evolution. Lamarck does not separate the two very well, and subordinates the first to the second throughout his book.

Lamarck's conception of the law of evolution he gives in the following paragraphs:

> Nature has produced all the species of animals in succession, beginning with the most imperfect or simplest, and ending her work with the most perfect, so as to create a gradually increasing complexity in their organization: these animals have spread at large throughout all the habitable regions of the globe, and every species has derived from its environment the habits that we find in it and the structural modifications which observation shows us (p. 126).
>
> We must first recognize that the general series of animals arranged according to their natural affinities is a series of special groups which result from the different systems of organization employed by nature; and that these groups are themselves arranged according to the decreasing complexity of organization, so to form a real chain (p. 68).

The chain series concept was, of course, not new with Lamarck, but the following modification is:

> I do not mean that existing animals form a very simple series, regularly graded throughout: but I do mean that they form a branching series, irregularly graded and free from discontinuity, or at least once free from it. . . . It follows that the species terminating each branch of the general series are connected on one side at least with other neighboring species which merge into them (p. 37).

Lamarck thought of the animal kingdom as a great family-tree; indeed he illustrates his idea with a crude tree. Now it is precisely this concept of a branching series that distinguishes the modern theory of evolution from all that precede it. To Lamarck falls the honor of adding this essential feature.

The proofs for the law of evolution are usually assembled into three groups.

to form the arguments from comparative anatomy, from embryology and from paleontology, respectively — somewhat after the fashion of books on theism. Most of the evidence given by Lamarck falls into the first group.

The mutability of species suggested itself to Lamarck as an explanation for the difficulties he encountered in his systematic work. It should be noted that Lamarck, like Darwin, speaks of the evolution of species and genera. Modern writers seldom descend below the larger systematic groups in their discussion of the evolutionary process.

> The almost universally received belief [Lamarck writes] is that living bodies constitute species distinguished from one another by unchangeable characteristics, and that the existence of these species is as old as nature herself (p. 31).
>
> Meanwhile, the farther we advance in our knowledge of the various organized bodies . . . the greater becomes our difficulty in determining what should be regarded as a species, and still more in finding the boundaries and distinctions of genera.
>
> According as the productions of nature are collected and our museums grow richer, we see nearly all the gaps filled up and the lines of demarcation effaced (p. 37).
>
> How many genera there are, both among plants and animals among which the number of species referred to them is so great that the study and determination of these species are well nigh impracticable! The species of these genera, arranged in series according to their natural affinities, exhibit such slight differences from those next to them as to coalesce with them. These species merge more or less into one another . . . so that there is no means of stating the small differences that distinguish them (p. 37).

Darwin records a similar experience in the "Voyage of the Beagle." As he sailed southward along the South American coast he noted the gradual replacement of species by others closely allied to them. Later at the Galapagos Islands he was struck by the slight differences that separated the birds of the several islands from each other and from their relatives on the adjacent mainland. The likenesses and differences were those found in the individuals of a human family, which everyone attributes to descent from a common ancestor.

The other evidence given by Lamarck for the mutation of species is adaptation. Lamarck found that everywhere in nature animals seemed specially fitted to live where they were found. He could not help but think that species had suffered modification to fit them for their particular environment.

The evidence that Lamarck assembled to justify his belief in evolution would all be included to-day in the argument from comparative anatomy. He cites the foetal teeth found in some whales and interprets them in accordance with his theory, but otherwise embryological evidence is lacking, as one might expect from the state of that science before von Baer. Lamarck could lean even less than Darwin on the infant science of paleontology. He seems to have doubted that any species was really extinct, especially of higher vertebrates. The explanation for this may be that Lamarck was best acquainted with the then recent and sensational discoveries of Cuvier in the Paris basin. The rocks of this region are of comparatively recent date geologically, and afford fossil vertebrates closely allied to living forms.

The differences between fossil and living invertebrates, however, did not wholly escape him. He suggests as an explanation:

> May it not be possible on the other hand that the fossils in question belong to species still existing, but which have changed since that time, and become converted into similar species that we now actually find (p. 45).

So much for Lamarck's conception of the fact or law of evolution, and the evidence he brought forward for it. As has been said, he devoted but a small part of the discussion to this part of his

theory and was chiefly concerned to suggest and establish the causes or factors by the operation of which the evolutionary process was brought about. These causes or factors are Lamarck's best known contribution to the general evolution theory, and are linked with his name, as natural selection is with that of Darwin.

The primary factor Lamarck thought to be some unknown cause which impelled living matter to become more complex in structure and function. To this cause he refers only vaguely and indirectly. The clearest reference is in the following sentences:

> If the factor which is incessantly working towards complicating organization were the only one which had any influence on the shape and organs of animals, the growing complexity of organization would everywhere be regular. But it is not; nature is forced to submit her works to the influence of environment, and this environment everywhere produces variations in them (p. 69).

The paragraph just quoted is worth emphasis, for it has been overlooked by the majority of writers on Lamarck's theory. Exactly what Lamarck had in mind is hard to say. Osborn thinks that Lamarck did not contemplate a "perfecting tendency," and nothing elsewhere in the text suggests that he did. Perhaps Lamarck thought that the effect of environment would not be more than to produce lesser adaptations in preexisting forms, and that the production of radically different types, such as amphibia from fishes, would require a cause quite independent of environment.

A far more important cause of evolution, to Lamarck, was the interaction of the species and its environment. This factor he explains and illustrates in considerable detail, and formulates into his well-known laws. In the "Zoological Philosophy," these are two in number.

> First law. In every animal which has not passed the limit of its development, a more frequent and continuous use of any organ gradually strengthens, develops and enlarges that organ, and gives it a power proportional to the length of time it has been so used; while the permanent disuse of any organ imperceptibly weakens and deteriorates it, and progressively diminishes its functional capacity, until it finally disappears.
>
> Second law. All the acquisitions or losses wrought by nature on individuals through the influence of the environment in which their race has long been placed, and hence through the influence of the predominant use or permanent disuse of any organ: all these are preserved by reproduction to the new individuals which arise, provided that the acquired modifications are common to both sexes, or at least to the individuals which produce the young (p. 113).

The evidence, or lack of it, for these laws need not be discussed here. It should be noted that the laws as they read in the "Zoological Philosophy" make no provision for the origin of absolutely new organs. In a later work Lamarck expands his two laws into four, the second of which provides for this omission, and, as given by Osborn, reads:

> The production of a new organ or part results from a new need or want, which continues to be felt, and from the new movement which this need initiates and causes to continue.

One can not rise from the reading of the "Zoological Philosophy" without wondering why it failed to impress the generation to which it was addressed and has been imperfectly understood ever since.

The contemporaries of Lamarck were dominated by catastrophic geology on one hand, and by the fag end of the Linnean era on the other. A modern evolution theory and eighteenth century geology are utterly incompatible. Neither would enthusiasts for classification welcome such slippery things as mutable species. Lamarck's first task should have been the methodical accumulation of evidence to prove that evolution really has taken place. Instead he did little more than summarize his personal im-

pressions. Then, taking the law of evolution for granted, he devoted his time to the discussion of the causes which might bring evolution about. His readers, decidedly not convinced of the reality of evolution, would not seriously entertain arguments for its causes. To make matters worse, most of the arguments that Lamarck advances for his causes of evolution are really illustrations and hence only concrete restatements of his thesis. A rigid proof of his laws transcended the knowledge of his day, as it still does ours.

To-day Lamarck is recognized as a scientific genius of the first order, the greatest figure between Aristotle and Darwin. Yet he is continually damned with faint praise. Eulogies are nearly always mixed with detractions. The credit for the uniformitarian concept has properly gone to Hutton and Lyell who gathered the evidence to prove it. For the same reason the glory for establishing the law of evolution has gone to the generation that followed Lamarck. Attempts have been made repeatedly to withhold credit from Lamarck for the laws or factors which are his chief contribution to biological thought. As is well known, Erasmus Darwin expressed substantially the same ideas a few years before Lamarck published. Darwin's statements are scattered here and there through the "Temple of Nature" and two other poems, and are vaguely sketched in a medical treatise entitled "Zoonomia." Despite any direct evidence, it has been insinuated more than once that Lamarck borrowed from Darwin without giving credit. Darwin's conception can be reconstructed only after a laborious plodding through a mass of doggerel, and by picking out a sentence here and there in the chapter on Generation in the "Zoonomia." After giving fullest credit to Erasmus Darwin's stimulating originality, surely some ought to be left for an independent thinker who worked out the same position and, in addition, formulated it in clear, definite and intelligible fashion.

No small part of the hostility to Lamarck among present-day scientists arises from *a priori* objections; different of course from those that closed minds to him a century and a quarter ago, but perhaps just as unreal. Evolution was to Lamarck, as it was to Charles Darwin and Huxley, not so much a progress upward as an adaptation to a changing environment. The three differed as to what part environment played, but all could agree that without a changing environment there would have been no evolution. Now present-day zoological thought is dominated by experimental physiology and genetics. The undoubted success of the experimental method in both fields has led many to prefer an evolution theory that will work *in vacuo*, or better *in vitro*, one that will operate without regard to environment. Accordingly the evidence for adaptation in nature is ignored or denied, and evolution theories that include adaptation as an essential part are opposed. Surely, the evidence of paleontology and of animal and plant distribution can not be ignored, even if it is not amenable to present-day experimental methods. When this is recognized a greater interest in Lamarck's theory can be expected.

The proof of Lamarck's factors, like the proof of other proposed causes for evolution, is likely to be a long and arduous affair. Those who believe that Weismann has disproved or that Guyer has proved the essential part of Lamarck's laws alike overlook the inherent difficulty of paralleling in a laboratory what is, by hypothesis, a secular process.

WILLIAM EMERSON RITTER

WILLIAM EMERSON RITTER: BUILDER

By Dr. FRANK E. A. THONE
SCIENCE SERVICE, WASHINGTON, D. C.

and Dr. EDNA WATSON BAILEY
UNIVERSITY OF CALIFORNIA

SEVENTY years is no longer regarded as the age of a man; we think now of a septuagenarian only as one who has begun his second maturity. Yet enough remains of the septuagesimal tradition that when a man reaches seventy we think it not inappropriate to pause and take stock of the things he has done to justify his length of days upon the earth. The recent anniversary of the birth of Dr. William Emerson Ritter called forth a group of communications from friends[1] who have worked with him at various stages in his scientific career, and these were of such character as to make it seem worth while to gather up their spirit and set it forth briefly in one place.

The stories of Dr. Ritter's coworkers begin with his coming to the University of California almost forty years ago, but the roots of his life as a scientist go much deeper than that. They apparently go back to the fundamental stuff of his mental makeup, and have been a part of him since he has had being at all; at any rate Dr. Ritter says that he can not remember a time when he was not interested in the things of natural history. As a boy on his father's pioneer farm in Wisconsin, he "could not step over a bone of a dead animal lying in the woods without stopping to examine it."

His first sally into the world of learning was made as a schoolmaster. The early days of the last quarter of the nineteenth century were exciting times for schoolmasters of a scientific turn, with the echoes of the first battle over evolution still sounding around the world, and the first giants of the modern dispensation of science in America striding among their startled brethren of the classics and the humanities on university campuses. Some of Joseph LeConte's writings fell into young Ritter's hands, and he went over the mountains forthwith, to search for this new kind of gold in California.

In those days all the natural history sciences at the University of California were lumped into one department and Joseph LeConte was their sole teacher. A few of the young men who came to him found they were more interested in living beings than in the story of the stones, and they began to collect and dissect and to roam the hills and beaches on their own account. The yield of these first efforts in practical natural history at the University of California was a rather remarkable group of naturalists; besides Ritter there were John C. Merriam, Theodore S. Palmer, W. L. Jepson and a bit later S. J. Holmes, Frank W. Bancroft and H. B. Torrey.

His first degree in science out of the way, Ritter did three very important things: took charge of the work in zo-

[1] Professors C. A. Kofoid and S. J. Holmes, of the University of California, Professor F. B. Sumner, of the Scripps Institute for Oceanography, Dr. J. McKeen Cattell, as chairman of the Executive Committee of Science Service, President R. M. Hughes, of Miami University, Dr. Edna Watson Bailey, of the University of California, and Mr. H. L. Smithton, friend and business associate of the late Mr. E. W. Scripps.

ology at the University of California, married Mary E. Bennett and went east to study more zoology at Harvard and incidentally to take his doctorate there, continuing afterward abroad, at Liverpool, Naples and Berlin. The first step cut out his first big task for him, that of organizing zoology at his alma mater; the second and third equipped him for this as well as for later tasks.

That he went to Harvard for his graduate work is significant for more than his formal training in zoology. His period there was during the heyday of the group of great Harvard philosophers. Having something of a constitutional weakness for the views of philosophy the exposure at this time and the later exposure to the same views through the Philosophical Union at the University of California brought on finally the disease of dissatisfaction in about equal degree with all varieties of subjectivistic metaphysics, on the one hand, and all varieties of materialistic metaphysics on the other.

Restoration to spiritual health came at last in the organismal conception of life combined with the natural history method of philosophizing. Some of the fruits of the intellectual clarification attained have been various books and journal articles, and various building operations, fashioned in accordance with the ideas elaborated in these writings.

Thus equipped and with such an outlook he found himself plunged into his work as the first teacher of laboratory zoology on the American Pacific coast. With all the rest he carried on a solid amount of research work, largely on ascidians and enteropneusts. He founded and edited the university series of publications in zoology, took a prominent part in reorganizing and revivifying the California Academy of Sciences, and shared in various scientific expeditions. It was a crowded dozen years.

The beginnings of one of the major enterprises of Dr. Ritter's whole lifework were taking form during this same congested period. They are best told by his colleague and friend of many years, Professor Charles A. Kofoid, of the department of zoology, University of California. In an unpublished article, prepared for this birthday celebration, Dr. Kofoid says, in part:

As early as 1900, Professor Ritter was casting about for ways and means for starting a marine station on the Pacific Coast which should serve the universities of the Pacific Coast as Naples had served those of Europe, or Woods Hole the colleges and universities of the East. In the summer of 1901 he gathered about him at San Pedro in an old bath-house transformed into a laboratory a group of his colleagues and students from Berkeley. The Oldroyds, the conchologists, came down from their truck farm, and teachers from the Normal School and high schools, the professor of anatomy from an osteopathic institution all joined with a will in a never-to-be-forgotten biological "bailo" which lasted all summer. An improvised dredging outfit worked by hand and back was outfitted in the *Elsie*, a forty-foot gasoline launch, and with this and 200 fathoms of cable, a deep-sea thermometer, a plankton net, we attempted to explore the continental shelf from the Coronados to Catalina, with the aid of the osteopath's sturdy muscles.

The final result of this infant enterprise is to be seen in the Scripps Institution for Oceanography. The manner in which this was accomplished is one of the all-too-few romances of science. Unappalled by the inevitable deficits at the close of each season, Dr. Ritter never gave up for an instant his dreams that the way could be found to make the enterprise a permanent one. In the summer of 1903 the San Diego Chamber of Commerce at the instigation of Dr. Fred Baker, of Point Loma, undertook to finance by local subscription a summer's work of the University Marine Station. Two of the principal donors to the meager fund were Mr. E. W. Scripps, of Miramar, and his sister, Miss Ellen B. Scripps, of La Jolla.

These two donors had been long associated in newspaper and news-gathering enterprises, and their interest at first was only that of generous public-spirited supporters of a local enterprise. Out of this relation, however, there grew up from the very first a close and ever enlarging intellectual attachment and personal friendship between Dr. Ritter and these donors.

The attachment between the men rested upon a mutual understanding of certain rather deep-seated motives which guided these two men, who otherwise differed greatly in almost all particulars. The one was a masterful, dominating man of affairs, with a largely assumed indifference to culture and refinement, but withal with the keenest of intellectual grasp of the world's thought and life, and, under the mask of realism, a great idealist. The other came from the academic shades with the aspirations of the idealist and a program devoid of all immediate practical implications. The two had this in common, both were inquirers, both were earnestly seeking the truth, and both were believers that the truth, science, would set men free, if men could only come to know the truth.

The first Ritter-Scripps undertaking was the founding of what is now the Scripps Institution for Oceanography, at La Jolla, California. In this they had the active cooperation, as well as the very considerable material support, of Miss Ellen Browning Scripps. The "Scripps Institution for Biological Research of the University of California" resulted. It was designed as a year-round institution, with a permanent staff of full-time research workers.

Here was in germ an institution with a program of research on the life of the Pacific Ocean the carrying out of which would require a lot of team work. Fundamental investigations were the aim which no individual working alone could possibly compass. Hence the necessity for a salaried staff elected with reference to their special but correlated tastes, and trainings.

At the beginning, terrestrial as well as marine biology was contemplated in its program; but its location, if nothing else, inevitably caused the institution to look seaward ever more and more. For several years antedating his retirement as director, Professor Ritter considered such a modification of policy of the institution as would make it more strictly oceanographic, with a corresponding change of name.

His recommendation of such change was adopted by the regents of the university and a successor to the directorship sought in accordance therewith. After many months of search for the right man, the post was accepted by Dr. T. Wayland Vaughan. Shortly thereafter the name was changed to "The Scripps Institution of Oceanography," the understanding being that oceanography should be construed in the broadest sense. All aspects of the Pacific Ocean, both physical and biological, come at least nominally within the institution's research program. Thus, there now exists in vigorous infancy a full-rounded oceanographic foundation, the first in the Pacific area and in the Western hemisphere.

The characteristics of this institution which have given its activities unity and coherence during a life of many changes in name, place and now in leadership, are best summed up in Dr. Sumner's greetings from the Scripps Institution of Oceanography: "Despite the apparent unrelatedness and even incongruousness of the several branches of the institution's activities in past years, there have always been certain underlying ideas which brought them under a common viewpoint. For the Scripps Institution has had a creed, which its members have repeated with child-like faith, following the words of their father-confessor. One of the articles of this creed has been the importance of studying the relations between the organism and its environment. Another has been a recognition of the one-sidedness of either field or laboratory study, considered by itself, and the consequent need of combining the two for a proper understanding of vital phenomena. Still another has been the necessity of employing rigidly quantitative methods, so far as these may be applicable. Finally, the organism itself has been wholeheartedly recognized as

having a real existence, in its own right, and not merely allowed a provisional existence, pending its analysis into chemical, morphological or genetic elements.

"Now I think that most of us, at the institution, may fairly claim to have accepted the foregoing as working principles. That the Scripps Institution has no monopoly of this particular set of principles may be readily granted, but their explicit formulation for the practical guidance of a research establishment was certainly novel."

While Dr. Ritter was still director of the Scripps Institution, Mr. Scripps conceived the possibility of an institution for popular education in science through the daily press, in whose power he had great faith. Preliminary to a move in this direction, Dr. Ritter took a long swing around the circle of American universities, sounding out scientific opinion. Things looked propitious, and so Science Service was called into being. For the new organization a board of trustees was formed, representing the National Academy of Sciences, the National Research Council, the American Association for the Advancement of Science, the newspaper profession and the E. W. Scripps estate; and Dr. Edwin E. Slosson was called from the editorship of the *Independent* to be its director. The results to date appear to give ample justification for Mr. Scripps' original idea, and the cooperation of the scientific world speaks well for its confidence in Professor Ritter and Dr. Slosson.

We have Professor Ritter's own word for it that the direction of his penetrating eye and still more penetrating reflection toward human conduct was due largely to the continual insistence of his friend E. W. Scripps. "This damned *human* animal—what is he?" To the bystander it seems likely that the fact that Mr. Scripps asked that question at all was due to his association with William E. Ritter. It is hardly the ordinary thing to find a business man, a humanist and a philosopher of sorts turning to a biologist for information as to the ways of men. Something in Mr. Scripps' knowledge of men—admittedly extraordinary—led him to feel that this particular biologist could interpret us to ourselves with sanity, science and common sense, could he but be badgered into the undertaking. Mr. Scripps' line of reasoning seems to have been: if scientific knowledge is useful and indeed indispensable to the most efficient making of glass and steel and houses and newspapers, it will in all probability be found to be equally useful and perhaps indispensable to the most effective conduct of all human affairs. In these he included, not just those humble affairs of getting food and clothing and curing ailments, but those high affairs of love of God and man, faith and hope and loyalty.

Like other thoughtful men of affairs, Mr. Scripps was haunted by the Malthusian specter. He realized that much of the accepted doctrine concerning the increase of population and its problems is based on erroneous or insufficient data. To assemble adequate and trustworthy information, on which to base decisions in the economic and social fields, the Scripps Foundation for Research on Population Problems was placed at Miami University, under the immediate direction of Professor Warren S. Thompson.

This mode of approach to the general enterprise of bringing science to bear on vital human concerns was, Professor Ritter insists, primarily Mr. Scripps' own venture. But neither he nor Mr. Scripps felt that study of human society alone could solve the knotty problem of what a single human being is, psychobiologically considered.

Faced with this task, Professor Ritter began to apply his naturalist's methods, as was his life-long custom. According to his own testimony, the naturalist's best motto is: "Neglect nothing." Applied to a creature of the complexity of an amoeba, this constitutes a sizable lifework. Applied to a human being, the task is staggering. It has called for delving with patience and precision into an enormous mass of material. Psychology, physiology, neurology, anthropology, sociology, with their many ramifications, have been explored and made to yield tribute. An onlooker at these tremendous labors is aware of a very good reason why biologists have not long since dealt thus with humans. The mass of facts and interpretations of facts to be synthesized is so great that we shall not often find a mentality able to cope with the task, or a temperament willing to tolerate its appalling exigencies. The mass of material demanding attention now is enormous compared to that available in Darwin's time. It is cause for genuine satisfaction that Professor Ritter has done certain fundamental thinking so thoroughly it need not be redone for some time. In the future, the humanist seeking sound scientific foundation for his concerns will find safe conduct through a great mass of irrelevant information and fruitless theorizing, because one man with human sympathy and superhuman patience has so faithfully "neglected nothing."

Another well-established procedure of the naturalist has entailed for Professor Ritter still further labors, and has yielded him even richer returns in the way of insight into humanity than that achieved by his comprehensive study of men alone. The methods of comparative anatomy and comparative embryology are familiar to all biologists for their fruitfulness. Men are to be understood as to conduct quite as they have long been understood anatomically. When we first made the acquaintance of the MSS of the "Natural History of Human Conduct" now in press, we read more or less patiently through long analyses of the behavior of ants, of woodpeckers, of beavers; of elk, and trout, and mayflies; but nothing at all as to the behavior of men, with whom the book was supposed to be specially concerned. It was a long while before we understood that when once we shall have achieved insight into the doings of woodpeckers and other folk, the key to the whole riddle will be in our hands. For a fuller explication of that riddle, we look to the next book, now approaching completion, "The Natural Philosophy of Human Conduct."

But significant information as to human animals comes not only from brute animals, but from the human animal himself while he is in the making. A new-born baby is anatomically pretty largely achieved; behavioristically, he has only entered the "gastrula stage" of his development. To study conduct in early childhood offers fascinating possibilities. The least exacting of environments, permitting the greatest freedom of behavior to children, is found in a modern nursery school. Professor Ritter's latest venture has been the establishment, in cooperation with another agency, of a Nursery School in Oakland, California. This institution is under the general direction of one of his former students, Edna W. Bailey. What glass-fronted aquarium tanks are to the observation of eels and starfish, nursery school play-spaces are to the study of the young human animal; with the added advantage of freedom and "every-day-ishness" quite impossible to the imprisoned sea creatures. There is no doubt that just this careful individual study through long stretches of growth will yield insight into adult conduct,

exactly as honest and painstaking analysis of animal activities gave the clue to their significance for human activities.

This latest phase of Professor Ritter's work is peculiar in that, while most of his life work has been directed toward pure science, this enterprise is concerned also with practical applications. Because of his insight into the nature of human capacity for regulating conduct with regard to organismal welfare, the results of these present observations are bound to be of arresting importance for education. Perhaps it is not at present justifiable to speak of education as an applied science; but if the trail which Professor Ritter is now blazing is carried through to its goal, there will be available psychobiological knowledge adequate to the creation of such a science.

We are agreed without argument that "the race moves forward on the feet of little children"; we are willing to spend free-heartedly to smooth the road before these feet. To bring the great learning, the keen powers of observation, the sure logical mind, the fruit of a lifetime's ripened scholarship, into the service of children, not merely to smooth the old road, but to strike out a new and safer way to more abundant life—that seems a not unworthy climax to the life's work of a gentleman and a scholar who loves his fellowman. May his strength and his days be equal to the undertaking!

HOW FAST CAN MAN INCREASE?

By Professor EDWARD ALSWORTH ROSS
UNIVERSITY OF WISCONSIN

THE basis of our reproductive outfit comes, of course, from our prehuman ancestors. But the human period—at least half a million years if we may trust the prehistorians—affords an abundance of time for man's bodily evolution. In the course of this eon the human chin, the nose, the forehead, the big brain, the S-curved backbone, the straight thigh bone, the opposable thumb, the plantigrade foot and various minor bodily features marking off the human from the subhuman, are supposed to have reached their present stage. While the physique of man was thus evolving there *may have been* a development in the direction of greater prolificacy. This might be either by perfecting the generative apparatus or by sharpening the sex appetite.

SUPER-FECUNDITY AS A SURVIVAL ASSET

For this cause! Early man possessed in his brain an organ of use to him in living outside the natural dwelling-place of the prehumans; so he became the animal of least restricted habitat. But as man, overflowing his boundaries, met the trying conditions of life outside the warm forested region which was the home of his tree-dwelling, fruit-eating ancestors and had to cope with harsh climates or new enemies, and subsist upon strange food, his death-rate must have risen. Without weapons or defense, without remedy for injury or disease, dependent for food and shelter upon the chance offerings of nature, primitive men had nothing but their fertility with which to make good the destruction wrought upon them by the many hostile features of their environment. Often they must have had wit enough to avoid being promptly snuffed out, as is the animal clear out of its natural habitat, but not enough to make real headway against their foes. Many a human group, no doubt, wandered into a life so hard that as a rule more died than were born. Hence it disappeared. With a little more fertility it could have survived. Thus, as early men drifted into more and more risky areas, there was a premium put on prolificacy. The less fecund strains would be supplanted by the more fecund strains. In this way conditions may have favored the spread not only of the breed with the larger brain, the defter hand, the better-made foot, but also of the stock with the greater fruitfulness, say twelve births to a couple instead of ten.

If thus the human species continued to evolve in body and mind as it spread ever further from the original center of dispersion, there is no mystery in its having acquired what in our eyes appears as an *overload* of fecundity. What else *could* happen? For, in the long run and other things being equal, the fast breeders would outmultiply and replace the slow breeders. Still faster breeders would supplant *them*. Constitutional prolificacy *had* to increase until it came to be so taxing to its possessors that it was almost as great a handicap as an asset. At this point, of course, its development would cease.

LIFE-SAVING AGGRAVATES THE PROBLEM OF EXCESS FECUNDITY

There is another development which makes man's high prolificacy appear a nuisance. If Thomas R. Malthus (1767–

1834), the first thinker to establish that the happiness of peoples is threatened by the results of man's super-fecundity, had broached his ideas to the men of the Old Stone Age fifty thousand years ago, I fancy that they would promptly have rejected his contention that *always population tends to increase faster than the means of subsistence*. They would have pointed out that they met untimely death from disease, wild beasts or other men far oftener than from hunger. They would have said: "When times are bad our tribe dwindles, when times are good our tribe expands. But, on the whole, we have no more fecundity than we need in order to assure self-perpetuation."

Nor in the European Middle Ages, say the twelfth century, did the worries of life center about the question of victuals. In the words of the Dean of St. Paul's:

> The population question slumbered. The miserable chaos into which the old civilization sank after the barbarian invasions, the orgies of massacre and plunder, the almost total oblivion of medical science, and the pestiferous condition of the medieval walled town, which could be smelt miles away, averted any risk of overpopulation. Families were very large, but the majority of the children died. Millions were swept away by the Black Death; millions more by the Crusades. Such books as that of Luchaire, on France in the reign of Philip Augustus, bring vividly before us the horrible condition of society in feudal times, and explain amply the sparsity of the population.[1]

Again, right after the visitation of the Black Death in the fourteenth century would have been a poor time to warn against large families. Hecker[2] finds that:

> Cairo lost daily, when the plague was raging at its greatest violence, from 10 to 14,000; being as many as, in modern times, great plagues have carried off during their whole course. In China, more than thirteen millions are said to have died; and this is in correspondence with the certainly exaggerated accounts from the rest of Asia. India was depopulated. Tartary, the Tartar kingdom of Kaptschak, Mesopotamia, Syria, Armenia, were covered with dead bodies—the Kurds fled in vain to the mountains. In Caramania and Caesarea, none were left alive. On the roads,—in the camps—in the caravansaries,—unburied bodies alone were seen; and a few cities only remained, in an unaccountable manner, free. In Aleppo, 500 died daily; 22,000 people, and most of the animals were carried off in Gaza, within six weeks. Cyprus lost almost all its inhabitants; and ships without crew were often seen in the Mediterranean, as afterwards in the North Sea, driving about, and spreading the plague wherever they went on shore. It was reported to Pope Clement, at Avignon, that throughout the East, probably with the exception of China, 23,840,000 people had fallen victims to the plague. . . . In Padua, after the cessation of the plague, two-thirds of the inhabitants were wanting; and in Florence it was prohibited to publish the numbers of the dead, and to toll the bells at their funerals, in order that the living might not abandon themselves to despair.

The researches of Thorold Rogers show that in the England of five centuries ago food shortage was by no means the chief bar to population growth.

> The habits of the people were favorable to pestilence. Every writer during the fifteenth and sixteenth centuries who makes his comment on the customs and practices of English life, adverts to the profuseness of their diet and the extraordinary uncleanliness of their habits and persons. The floor of an ordinary Englishman's house, as Erasmus describes it, was inconceivably filthy, in London filthier than elsewhere, for centuries after these events. The streets and open ditches of the town were polluted and noisome beyond measure. The Englishman disdained all conditions of health.[3]

Very likely there have been many periods in which all man's fecundity was needed to insure the upkeep or replenishing of the population, and the difficulty of obtaining the means of subsis-

[1] W. R. Inge, "Outspoken Essays," 1919, p. 67.

[2] "Epidemics of the Middle Ages," 1844, pp. 23, 26.

[3] "Six Centuries of Work and Wages," 1884, p. 118.

tence was by no means the chief source of his troubles and anxieties.

The Debate over the Origin of Superfluous Fecundity

Malthus made his case against reckless propagation about the beginning of the last century when British statesmen were losing sleep wondering how the swelling population of the towns could be fed. In his time he had seen the birth-rate rise 6 per cent. and the death-rate fall 25 per cent. Since it is obvious that on an island not made of gutta percha this must reach a limit, he contended—reasonably enough, one would think—that unless births are fewer deaths will be increased in number by "checks" generated or aggravated by growing population pressure, *i.e.*, *war*, *famine* and *disease*, until population ceases to grow. But in the third decade of the nineteenth century, thanks to industrialization and town crowding, the English death-rate rose and stayed up for sixty years. At the same time a colossal overseas movement of food made subsistence easier than ever to procure. So the impression grew up that the course of events had falsified Malthus's prophecies. Then, following upon the discovery of the real nature of infectious disease, came a great fall in the death-rate which has once more thrust the population question into the foreground.

In Malthus's time no one doubted that, some six thousand years ago, a benevolent God created man to be happy. As a clergyman Malthus was therefore hard put to it to account for our being created with a reproductive propensity quite in excess of current needs. Such a discrepancy seems to reflect upon the goodness or wisdom of God. Malthus could only argue weakly that man had been equipped with his imperious sex urge in order that by controlling it he might have opportunity to show character and prove himself a moral being.

Charles Darwin got his key to the development of species, the "principle of natural selection," from reading Malthus's "Essay on Population." As he read it dawned upon him that, if all species are as over-fecund as Malthus shows man to be, there will be a struggle for existence. Some individuals will go to the wall while others survive; and among the survivors will be those, otherwise fit, who happen to possess any advantageous variation in organ or trait. Thus is every species constantly molded into completer adaptation to the life conditions imposed by its environment.

It should be plain by now that our excess of fecundity is not a constant, but is relative and variable. It grows with progress in security, in peaceful association, in medicine, hygiene and sanitation. More individuals of each generation survive the perils of infancy; more reach adult life; more complete their reproductive period. So each generation has a bit more of excess fecundity to deal with. Writing to-day, when the infectious diseases are two thirds whipped and the mortality is but half of what he knew, Malthus could make a far stronger case than he was able to make in his time.

Of course, the foregoing is wasted on those who deny that man has evolved and insist that he was created just as he is. Since "God is good," it is impossible that our procreative propensity should ever prove a snare. Within the divinely ordained institution of marriage men and women may safely "follow nature." Hence, there is no "population question" save for peoples too lazy or wasteful or vicious or stupid to keep their food production ahead of the increase of mouths. Since no people is perfect, the orthodox are able to represent even the appalling poverty of the Chinese myriads as their own fault, as due to *under-production* rather than to

over-population. Thus all is shown to be for the best; we have but to go on and procreate as many children "as God sends."

Fecundity is not declining

We must reject the cheering argument of Herbert Spencer that civilization begets individuation and that, as individuation progresses, reproductive power declines. The fact is, the women of the most civilized peoples, if anything, are more fruitful than those of the less advanced. Theal found that 984 women of the Bantu blacks in South Africa had borne an average of 5.6 children. An investigator discovered that 160 Chinese wives, all over fifty years of age, had given birth on an average to 7.5 children. In Baroda, one of the native states of India, the average number of births for 28,011 completed families was 5¼. Four fifths of these women became wives at the age of thirteen or fourteen years. In the Punjab 34,561 unions of a duration of thirty years or more show 5.68 to a union. Ten thousand Bengal families in which the wife had been married at least thirty-three years yielded (including still-births) 6.34 progeny to a family. The genealogies of New England families show that in the first half of the eighteenth century the births per wife were 6.83. About 1912 an investigation of prolificacy in twenty-one rural counties of Minnesota showed that the wives born in Poland had produced on an average seven children in the course of fourteen and a half years of married life. When completed these families would certainly average ten or more children.

From the returns of the British 1911 census Stevenson calculated that the average number of children born to English couples married in the decade 1861–71 and surviving to 1911 was 6.79, while for couples married in the decade 1851–61 (when birth control was little known) the number was 7.28. While wives married twenty to twenty-four bore 5.83 children, those wedded fifteen to nineteen bore 7.41. Dunlop found that in Scotland women of the age group twenty to twenty-four who married 1861 to 1865 became the mothers of 7.8. In New South Wales the progeny of such unions was 8.32. The palm went to Scottish women married at the age of seventeen; their average was 9.02 children. The 1920 Census of Norway showed that for surviving couples who were married before 1888, the bride being but eighteen or nineteen years old, the type family was ten children. In Australia the births to wives married between fifteen and eighteen years of age and whose marriage had endured twenty-five to twenty-six years averaged 10.45. Doubtless similar figures would be found if such inquiries were prosecuted among the peoples of Central or Eastern Europe. It seems idle, then, to pretend that civilization solves the population problem by reducing the fruitfulness of women.

Maximum Rates of Human Increase

In a healthy population of normal makeup, in age and sex, whose fertility is checked by no other restriction than that of monogamous marriage, the birth-rate will range from fifty to sixty per thousand per annum. Birth-rates in the neighborhood of forty per thousand are not hard to find. This figure measures the fertility of Saxony thirty years ago, of Bosnia and Bulgaria just before the war, of Ceylon in 1917. In this class are Chile, the Central American republics and the West Indies. Birth-rates around forty-five we come upon in British Honduras in 1920 (45), Santo Domingo in 1910 (46.3), pre-war Roumania (43.1), pre-war Egypt (43.6), pre-war Russia (45.6), Serbia, 1886–1895 (43.4), Hungary, 1876–1885 (44.4), and Guatemala, 1876–1885

(45.2). A birth-rate of forty-nine was registered by Russia, 1886–1895, and in India at about the same time. It is so difficult to get a backward people to register all its births that many of these figures need to be revised upwards. Probably fertility comes nearest to natural fecundity in French Canada, where the devout *habitants* are forbidden by their priests to attempt any control over the size of their family. Quite often a priest, after returning for his parish a number of births which shows a rate of from fifty to fifty-five per thousand, adds the warning "many births are not reported." Certain parts of Quebec and certain regions in the Orient and Oceania appear to hold the world's record for prolificacy.

The advanced peoples have cut their death-rates per annum to sixteen, fourteen and even twelve per thousand; but such low figures are not for the quick-breeding peoples, which generally are rather ignorant, superstitious and fatalistic—poor soil for life-saving programs. Then, too, a prolific population will not only include a host of children—so frail and perishable—but frequent pregnancies and large families bring always in their train a high infant mortality. It seems safe to predict that even in this Golden Age of public hygiene no people with an annual birth-rate of fifty will have a death-rate below twenty—which gives an annual growth of 3 per cent. per annum. Such a population will double in about twenty-three years. In the last decade of the eighteenth century, when immigration was eligible, the increase of the American people averaged 30.5 per thousand a year, while in the first decade of the nineteenth century the rate was 31.5 a year. So far this performance holds the record.

We know of no contemporary population which actually attains this rate of natural increase. All the peoples bright enough to achieve a low death-rate are too wise to multiply in the blind way animals do. So many couples curtail family that by no means all the nation's fecundity is utilized. The highest annual rate of natural increase attained by any country throughout the entire period of authentic vital statistics was that of New Zealand, 26.6 per thousand for the decade 1876–1885. Only a country of recent settlement with a very small quota of old people could make such a showing. Quebec, Manitoba and Argentina report an excess of births above deaths of about twenty, which would double the population in thirty-five years. Just prior to the outbreak of the war, Roumania reported a natural increase of 18.4 and Bulgaria, 18.6. This is the maximum for Europe and would suffice to double the population in thirty-nine years. Russia had a margin of 17 in 1911; Holland follows with 16.3 in 1920—a gain not purchased by a very high birth-rate, but by combining a fairly high birth-rate with a very low death-rate.

Utilizing the life-saving means now available, a flourishing and enlightened modern population which welcomed large families might grow from its own loins at a rate which would double it in twenty-three years. To be sure, no people wise enough to keep its mortality low consents to breed in such reckless fashion; but we are told that it should do so if it is to avoid "sin."

THE BALTIC AMBER DEPOSITS

By Professor EDWARD W. BERRY
THE JOHNS HOPKINS UNIVERSITY

FROM the days of the Neanderthalers and Cro-Magnons, and possibly still earlier, man has been interested in the riddle of existence. Dim and feeble must have been the thoughts which the men of the Old Stone Age could spare from the pressing daily problems of food, shelter and life itself, for consideration of less mundane things, but that these had a considerable place in their thoughts is shown by the ceremonial burial of their dead and the ritualistic magic mirrored in cave art.

The accumulation of knowledge with the progress of the race has served to sharpen our interest in the meaning of it all, and although we are still ignorant of whence we came or whither we are bound, we do know that we are a part of a mighty current, eons old—a continuous garment of life with a warp of immutability and a constantly changing woof. We shall probably never be able to answer the Why? but we can discern rather clearly the main outlines of a history covering millions of years, and herein lies the great appeal of paleontology—the record of evolution, the chief handmaiden of historical geology and the principal scribe in the autobiography of the earth.

The votaries of the temple of science, while they may not bask in Roman luxury, will escape much of the pettiness of life and if they are really called to this high calling, will have more than their share of happiness. John Masefield in his introduction to a new edition of the "Travels of Marco Polo" says, "it is only the wonderful traveler who sees a wonder." Here is a moral for every one! The twentieth century mind is too cursed with pragmatism, the spirit that sees beauty in the world appears to be dwindling all too rapidly. A forest to many is merely so many potential board feet of timber; a crag, that might be the haunt of spirits, is merely a source for road metal or building stone. There is the best of precedent however for saying that "life is more than meat, and the body than raiment."[1] After all, as Rebecca R. Williams puts it, " 'Tis the set of the sail and not the gale that determines the way we go." Information must be changed to inspiration. We must feel sympathetic to Vergil's sonorous "Gods of the Rocks and Soil" as the thrilling first line of the epic of geology. Thus attuned we may learn much concerning the past.

If you mention the city of Danzig to a paleontologist, does he think at once of the lamentable failure of allied diplomacy in recent years? Not at all! He thinks, if he is the sort of a traveler that Masefield had in mind, of the brown coal deposits north of the town between Putzig and Rixhöft and the wonderful fossil plants that have been found in them. If you mention Königsberg eastward across the Bay of Danzig your paleontologist does not think of Hohenzollerns or other unpleasant things, he may not even know that it was the birthplace of Kant, but he will know of the marvellously preserved relics of the ancient world preserved in the Baltic amber, that has been washed up on the beaches of Samland, and collected by man during the last ten thousand years or more.

[1] Matthew 6:25.

Samland lies between the rivers Memel and Pregel—Königsberg is situated at the mouth of the latter. The peninsula proper projects at the eastern horn of the Bay of Danzig from between the Kurisches Haff and the Frisches Haff. The country is low and poor and comprises moors alternating with coniferous forests. The climate is cold and forbidding—quite different from what it was in the long ago. Contemplation of the present scene in Samland should not blunt one's mind to the wonder that can be extracted from this barren stretch of coast.

With our sails thus set to the breezes from the past let us see what sort of tale it has to unfold.

Even a non-smoker knows that the better pipes have amber mouth pieces and that amber beads are to be preferred to beads of glass or bakelite.

The use of amber in making articles for smokers is of course quite modern, since the habit was not introduced to the white race until after the discovery of America, tradition crediting its introduction into Europe to Sir Walter Raleigh.

The use of amber for ornaments, however, is older than human civilization. The men of the New Stone Age, or Neolithic as it is called, the time when polished flint weapons were in general use and the art of pottery making was first practiced, knew and valued amber. Amber beads have been found in burials of that early age estimated to be about twelve thousand years old. They are found in the relics of the Swiss Lake dwellers, who built their houses on piles over the water, practiced the first known primitive agriculture and lived nine or ten thousand years ago. They are found in the first known Mediterranean civilization (Minoian) that flourished on the island of Crete before the time of the Trojan wars, and in the tombs of the Etruscans who lived in Italy before the Romans, as well as in the earlier bronze age burials.

Various words in Hindu literature alluding to some mineral that attracted chaff when rubbed have been suspected to indicate amber, but this is very uncertain. Our word amber is said to come from the Arabic word "anbar," introduced into Spain by the Moors and derived by us from the Spanish. The early Greeks called it electrum, or that which attracts, because when rubbed it will attract bits of pith, dried grass and similar objects. It is interesting that this Greek word for amber is the origin of our word electricity which means so much more in these modern days than the mere property of attraction.

The Romans sometimes used the latinized form of the Greek word for amber, but more commonly, as by Pliny, for example, they called amber succinum from their word "succus," which means gum, showing that they understood the real nature of amber. This study of the origin of names and the names by which the same object is called in different languages is exceedingly interesting and often of great historical importance. For example, if we could be sure that the Sanscrit word grass jewel really meant amber we would know that this substance was well known in the most ancient Aryan civilization.

Amber is very inflammable and its germanic name alludes to this property, the German word Bernstein meaning combustible stone. In Finland and Esthonia amber is known as meri-kivi or merre-kivio, which means sea stone, and we would be at a loss to understand the significance of such a name did we not know that for ages the waters of the Baltic Sea have been washing out bits of amber from the sands and clays of its bottom and casting them ashore. Before the days when man was intelligent enough to search in the ground for amber in the same way as any other

mineral is now sought, the sole supply of amber was obtained by hunting along the coasts of the Baltic for it, exactly as we pick up dead shells along any sea beach.

Homer mentions amber several times in the Odyssey, especially as a Phoenician article of commerce. It is also mentioned in the Bible. Along with stone weapons of the chase amber was probably one of the earliest articles of European trade, Svensén, the Swedish archeologist, attributing the apparently prosperous Neolithic culture in southern Sweden to the trade in amber.

But we may know how amber looks and how it got its name and still be ignorant of its origin. If we were asked to decide whether it was animal, vegetable or mineral we should probably call it a mineral, which would not be far from the truth, although it is really of vegetable origin and is nothing but the fossilized gum or resin of plants that lived and died millions of years ago. In life it was almost identical with the drops of gum that you see on old cherry or peach trees, on balsam, spruce and pine, and on many other trees.

As thousands of different kinds of trees have lived and died and become extinct in the distant past of earth history, many different kinds of gum have been preserved in the ground, all of which, if it does not look different, is commonly spoken of as amber, although the earliest amber of commerce which came from the Baltic region of northern Europe has a certain definite chemical composition and is often called true amber. By chemical analysis we learn that the amber from which the beads were made that are found in Etruscan tombs in such quantities came from the Baltic, for the amber now found nearby in Sicily has a different chemical composition. Hence we assume that the amber deposits in Sicily were unknown to the ancients.

We now know amber of varying composition from a great many localities. Sometimes it has been given a special name, like cedarite from western Canada, or burmite for the Burma variety, or ambrite for the New Zealand variety, or roumanite for that which comes from Rumania. All of it looks much alike and has much the same physical properties, and usually can not be distinguished except by very careful chemical analysis.

It has been found at very many geological horizons in the rocks, from those of Cretaceous age, which are many millions of years old, down to the present. Almost always it is associated with beds of coal or in deposits that are highly carbonaceous and contain the debris of the trees which furnished the gum. Of the very many localities where amber has been discovered I know but three which are in the Equatorial Zone. These are Burma, in southeastern Asia, the island of Haiti, in our West Indies, and Colombia, in northern South America. This is interesting because there are a great many gum-bearing trees in the tropics, and we may expect to discover amber at many places in the equatorial zone when those regions have been more thoroughly explored.

If this were all the story of amber it would hardly be worth the telling, but it is only the beginning. In trying to picture the past life of our earth we depend almost entirely on what we call fossils, that is, on the traces of former life that are preserved in the rocks. Usually an organism has to have hard parts to stand much chance of remaining intact long enough to be buried by sediments and preserved for millions of years. Hence our fossils will be the bones of the higher animals, the shells of sea creatures and things of that sort, usually broken. Soft tissues always decay long before they can be sealed up in the rocks so that frequently animals that lived in the seas in swarms, like the

sharks, are known from their hard teeth alone, all the rest having been dissipated before burial.

Of the myriads of insects that have inhabited the world from the early days all that fell in the water were not snapped up by waiting fish, but many were buried, and we often dig their remains out of the shaly rocks. Occasionally these show the whole insect in a crushed carbonized mass. More often nothing but the wings are preserved, and although much information can be obtained from wings alone, they are nothing like as satisfactory as if we could have the whole insect for study.

Now amber contains fossils. Not all of it, to be sure, but where amber has been collected from a single region for thousands of years many specimens with fossils inside will have been encountered. Naturally the gum of a tree will not accumulate in quantities sufficient or rapidly enough to imprison anything large, but small objects will be caught in the sticky gum and covered by it, and these will be preserved in all the perfection of life; every lens of the insect eye, every hair on its legs or feelers, will be hermetically sealed and preserved for all time. It is as though nature were preserving these small forms of life for future students in the same way a scientist mounts objects for microscopic study in Canada balsam.

If you will notice the ants going and coming on a modern tree you will realize how easy it would be to entrap them if the tree exuded a gummy substance, or if you wish to try an experiment along this line tie a piece of sticky flypaper around a fruit tree in the garden with the sticky side out and after a few days examine it and see what a variety of things it will have caught. That this was similar to the way the fossils that we find in amber were caught millions of years ago we know because of the kinds of things which it contains. All are crawling or flying things or such as were light enough to be blown by the wind, such as small flowers, plant hairs, tiny shells and the like. Among crawling and flying things we would expect those that frequent trees to be the most common, and this we find to be true. Ants and spiders are exceedingly common in the amber, and among the ants the wingless workers are more common than the winged forms, for it is they that forage about over the vegetation. Just the opposite is true in certain insect beds laid down in water and covered with mud. In the latter we would expect the winged ants, flying about in swarms at mating time, to be drowned much more frequently than the wingless workers, and that is exactly what we do find in such water laid deposits.

One might expect that the chances of many different kinds of things being caught in such small amounts of gum to be exceedingly slender, and yet more than two thousand different kinds of insects, spiders and plants have been described from the Baltic amber alone. We have to remember that these amber trees made gum over many thousands of years and if the whole forest caught but one insect a day, in the course of ten thousand years that would mean three and one half million insects, and one has only to have a house painted during the summer to realize how numerous insects are in the world.

At any rate the amber trees that grew in northern Europe during a time that the geologists call early Tertiary caught many things in the gum or resin that exuded on wounded surfaces or dropped drop by drop to the ground. Many of these hardened pellets in all amber deposits are tear-shaped, just as they dropped from the trees, and this form of occurrence gave rise to one of the pretty legends of mythology, that of Phaëthon, and his sisters the daughters of the sun (Helios).

Phaëthon, because of the promise of the Sun his father, insisted that he be permitted for one day to drive the flaming chariot of the sun across the arch of the heavens. With the willfulness of youth he could not be persuaded of the skill necessary or the dangers to be encountered.

As the dawn opened the doors of the east and the stars and moon retired Phaëthon sprang into the chariot and delightedly grasped the reins. The impatient horses darted swiftly forward outrunning the morning breezes. Soon they realized that inexperienced hands held the reins, they rushed headlong, leaving the travelled path. Poor Phaëthon knew not how to guide them, even had he the strength. He forgets the names of the horses and knows not what to do. With terror he sees the monstrous forms scattered over the heavens —the scorpion, the crab, the serpent and the great bear. He drops the reins in his fright and the horses, entirely without restraint, rush hither and thither, now too near the earth and now far above it, the clouds begin to smoke, the mountain tops take fire, fields are parched, vegetation blazes, cities perish and the rivers dry up, even the sea shrank because of the awful heat. Earth screening her face with her hands huskily besought Jupiter for pity and relief.

Then Jupiter the omnipotent, calling to witness all the gods, including Phaëthon's father, mounted his tower and launched a lightning bolt against the foolish charioteer, who fell head-long and flaming into Eridanus, the great river. The Italian Naiads reared a tomb to his memory and his sisters, the Heliades, as they lamented his untimely end, were transformed into poplar trees on the banks of the river, and their tears, which continued to flow forever, became amber as they dropped into the stream. That is why in southern Europe these tear-shaped pellets of amber are often called the tears of Heliades (the sisters of Phaëthon).

We know more about the life and times of the Baltic amber than any other amber deposits because they are the chief source of commercial amber and have been worked for so many years. Since 1899 the deposits have been worked by the state and have produced between 150 and 250 tons of amber each year. The industry centers around the ancient city of Königsberg, where, as early as 1790, a scientific society was organized. This is known as the Physikalisch-Ökonomischen Gesellschaft, and it has been publishing memoirs (schriften) regularly since 1860. Much of our present knowledge of the amber fossils has been contributed to this series by a host of specialists, and it has been the natural repository of the results of the scientific activities of the region.

In the earlier amber days much of the present Baltic was a well-forested land surface with a genial climate. After some thousands of years during which the trees wept gum in small amounts and died and rotted away, leaving on the ground the gum they carried and which was gradually buried in the forest litter, the sea commenced very very slowly to encroach on this old land surface. As it gradually flooded the forest it worked over this forest litter, and that is why the surface of the pieces of amber are worn and rounded by wave action. Such of it as escaped destruction was finally buried in the muddy seabottom in what is now a bluish sandy clay.

This clay in which the amber is preserved was deposited at the beginning of a marine stage in this region known to the geologist as the Lattorfian or Sannoisian stage, and since the localities from which these terms were derived are classical it is of some interest to describe them briefly.

The Sannoisian was proposed by a French geologist (Munier-Chalmas)

FIG. 1. MAP SHOWING APPROXIMATELY THE DISTRIBUTION OF LAND AND WATER IN EUROPE DURING THE LATTORFIAN STAGE OF THE LOWER OLIGOCENE. LINED AREAS ARE MARINE, DOTTED AREAS ARE ESTUARINE AND CONTINENTAL DEPOSITS. ARROW INDICATES DIRECTION OF INVASION OF NORTH GERMANY BY THE LATTORFIAN SEA AND FAUNA.

from the exposures at the village of Sannois near Paris. Here lying on top of the gypsum, which is now rather generally referred to the upper Eocene (Ludian stage) the following succession of beds is seen. At the base a dark, pyritiferous and gypsiferous clay with fossil fishes, turtles, a few crustaceae and molluscs, occasional mammal bones and leaves, reaches a thickness of about thirty feet and evidently represents sediments deposited in salt water of lagoons along the coast, but cut off from the sea. Overlying this dark clay are lenses of light calcareous clay varying in thickness up to forty feet and containing a few mammal bones, chara fruits and fresh water molluscs, evidently recording a freshening of the lagoon waters by the rejuvenation of the adjacent watershed. Above the light-colored fresh water clays is a thickness of from six to twenty feet of thin-bedded (laminated) clay with brackish water molluscs like Cyrena and Cerithium. This is the *marnes à cyrenes* of the French geologists, and shows a slackening of stream action and a renewed access of marine waters. Above the Cyrenia marls there is from twenty-five to forty-five feet of massively bedded, greenish, poorly fossiliferous clay of marine lagoons, and this is overlain by the Brie limestone, the last being the basal formation of the Oligocene, according to Stehlin, the vertebrate paleontologist.

Since this section at Sannois was deposited under somewhat abnormal conditions and therefore does not contain a typical marine fauna, most geologists

prefer to use the term Lattorfian, proposed by Mayer-Eymar and derived from the little village of Lattorf or Latdorf in Anhalt. Here, overlying about one hundred feet of clay and lignite, is found about thirteen feet of fine-grained, glauconitic and sparingly argillaceous marine sand in which are preserved vast numbers of molluscan shells. This is all that represents the Lattorfian stage at this locality, since the darker marine sands overlying the greensand contain a marine fauna which shows them to be of middle Oligocene age.

Lattorf is near Bernberg on the railroad between Berlin and Magdeburg, and near the latter is the village of Egeln, which is almost as famous as Lattorf for the lower Oligocene fossils which it has yielded, since it is principally from these two localities that von Koenen, the great German paleontologist, described over 750 different species of fossil invertebrates—mostly molluscs.

Students have been puzzled to account for the difference between this north German Lattorfian fauna and the antecedent Eocene faunas of western Europe, and have also assumed that it spread eastward across southern Russia into western Asia. Recent work in the last region by Lukovic, although not entirely conclusive, indicates that the south Russian and western Asiatic faunas are older than those of north Germany and that the Lattorfian sea as we find it in north Germany invaded that region from southern Russia and that the ancestors of this wonderful Lattorfian marine fauna dwelt in the Caspian and Aral regions.

The accompanying sketch map of Europe embodies this new conception of the extent of the flooding of that continent by the Lattorfian sea. (See Fig. 1.)

This sea gradually spread over a part of the old amber forests and buried them under a mantle of marine sands forty to fifty feet thick.

That the present Baltic covers part of the old amber forest we know because in the wash of currents and waves much amber is worked out of the submarine amber deposit and washed up on all the shores of the Baltic and even as far away as southeastern England, and it seems evident from this that the southern basin of the Baltic and perhaps a part of the North Sea was covered by similar forests during the emergent period that preceded this advance of marine waters over the old land; indeed, Tornquist, in his account of the geology of East Prussia (1910), concluded that the amber forests covered the whole Baltic basin as well as the Scandinavian peninsula, Finland and northern Russia, so that a part was submerged by the Lattorfian sea and much remained emergent along its whole northern shores.

An alternative view to the one here advanced was that of Heer (1860) who assumed that the Lattorfian sea and the amber forests were contemporaneous, the latter growing on the uplands that skirted the northern shore of this sea and that the amber was carried into the sea by streams. This is seemingly confirmed by Ulmer's studies (1912) of the caddis flies found in the amber of which the larvae of seventy-three species in thirty-five genera are considered to have lived in fresh water torrents. Such physiographic conditions would account for the numerous coniferous trees and for the northern elements in the apparent mixture of northern and southern forms in the amber flora and fauna.

It fails to account for the southern elements unless we assume that the upland was lofty enough to embrace several altitudinal zones. Apropos of this question Wheeler in his recent study of the "Ants of the Baltic Amber" (1914) notes for these insects an exactly similar situation as is shown by the plants, namely, that the northern types greatly outnumber the southern, as if the south-

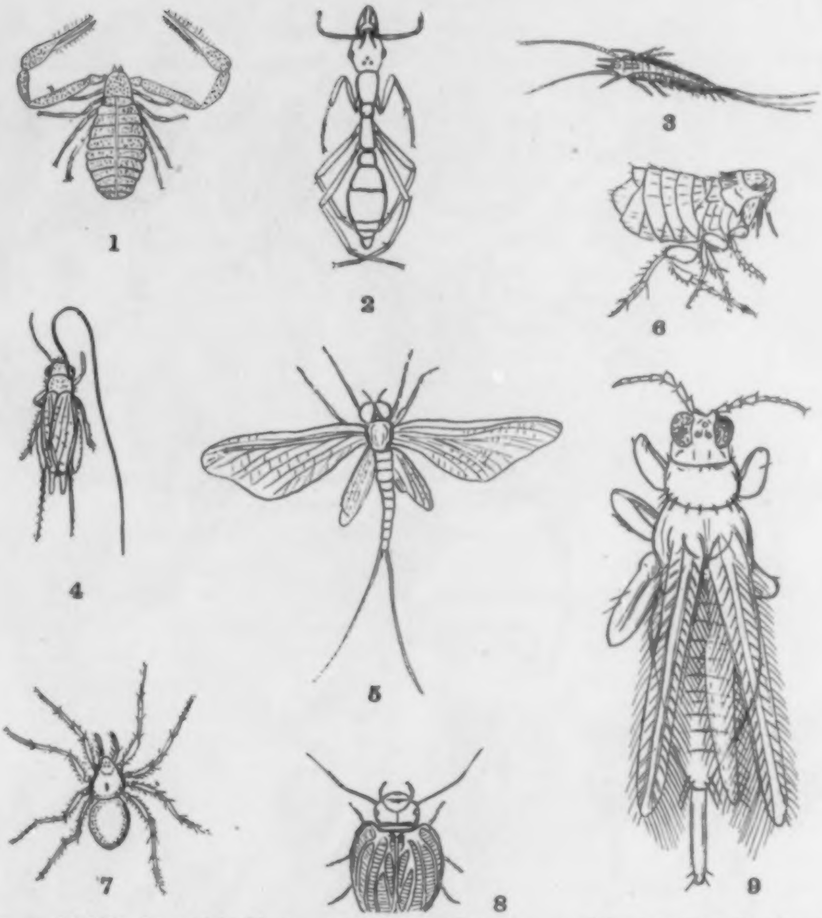

FIG. 2. 1. *Chelifer hemprichi* MENGE, ×9 (AFTER MENGE). 2. *Prionomyrmex longipes* MAYR, ×2 (AFTER MAYR). 3. *Machilus seticornis* KOCH & BERENDT, ×2 (AFTER KOCH & BERENDT). 4. *Gryllus macrocercus* GERMAR, ×1½ (AFTER GERMAR). 5. *Cronicus anomalus* PICTET, ×3 (AFTER PICTET). 6. *Palaeopsylla klebsiana* DAMPF, ×12 (AFTER DAMPF). 7. *Mizalia rostrata* KOCH & BERENDT, ×3 (AFTER KOCH & BERENDT). 8. *Sphaeropsocus kuenovii* HAGEN, ×15 (AFTER HAGEN). 9. *Stenurothrips succineus* BAGNALL, ×35 (AFTER BAGNALL).

ern were the survivors of the once dominant biota. If the region was one of warm lowlands and high uplands the plants and insects of the warm lowlands should outnumber the representation from the more distant highlands since the question of successful transportation would be a controlling factor, and this is not the case.

Eventually the Lattorfian sea receded and its marine sediments in the Samland region became a land surface which was soon covered with vegetation. During a long interval sands and clays, and especially swampy deposits, accumulated in the swampy depressions of this land, and the last was the source of the brown coal of the region. Many fossil plants are preserved in the brown coal series and although authorities are not entirely agreed as to the age of the series it is either later Oligocene or early Miocene


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and constitutes the youngest formation in the region beneath the relatively modern Pleistocene cover.

The problem of the age of the amber is a difficult one and well illustrates the problems of paleontology. As I have already mentioned, the amber contains a great variety of the most beautiful fossils, and some of the insects, spiders and flowers found in the amber are shown in the accompanying illustrations. (See Figures 2 and 3.)

The very wealth and completeness of the material overwhelms us, for the geological timetable is built up by carefully establishing the succession of organisms in the rocks, and these organisms ordinarily are those most favorably situated for burial and most capable of withstanding the ravages of time, such as aquatic forms with hard parts, among which the mollusca may be considered as the dominating caste.

If plants are represented it is by wood or the more durable foliage, and not, as in this case, by flowers. Thus we have the problem of comparing flowers and insects with a time scale made from shells and leaves, and there is this additional perplexing factor. It is quite generally agreed that the sandy clay in which the amber is found is correctly assigned to the Lattorfian stage, but say the opposition: Although the clay is of Lattorfian age it is obvious that the trees which furnished the gum, along with the insects that foraged over them, and the plants whose flowers were entrapped, lived at an earlier time when the region was land and not sea, and you are confusing the time of their collective burial with the time that they lived, which is quite a different thing.

This is incontrovertible logic, but it is not so disconcerting as it seems, since the sea invaded but a fraction of the forested country and the amber forests continued to line its shores. This we know from the occasional amber plants that occur throughout the Lattorfian marine deposits. Furthermore, the seconds of the geological time clock are to be considered as of a thousand years' duration, and many generations of organisms can run their course in that time.

Indeed it is almost certain that the amber fauna and flora represent a mixed assemblage of preserved samples of the life of the times over a very considerable interval if measured in years, so that one can never be sure that the organisms in one piece were the exact contemporaries of those in another piece. When you find plant lice with their attendant worker ants in one inclusion there is no doubt of their contemporaneity, but we have very few records of this sort, since the custom in all large collections has been to cut the amber into small blocks which are then polished and mounted.

Here again it is not as confusing as it sounds, since all can be shown to belong to the same general stage of earth history, and it matters little whether we

FIG. 3. 1, 2. *Sambucus succinea* CONWENTZ, × 1½. 3. *Cinnamomum prototypum* CONWENTZ, × 4. 4. *Antidesma Maximowiczii* CONWENTZ, × 5. 5, 6, 7. *Thesianthemum inclusum* CONWENTZ, × 5. 8, 9. *Hamamelidanthium succineum* CONWENTZ, × 4. 10. *Myrsinopsis succinea* CONWENTZ, × 5. 11. *Andromeda Goepperti* CONWENTZ, × 5. 12. *Oxalidites averrhooides* CONWENTZ, × 3. 13, 14. *Cinnamomum Felixii* CONWENTZ, × 4. 15. *Connaracanthium roureoides* CONWENTZ, × 3. 16. *Pentaphylax Oliveri* CONWENTZ, × 1½. 17. *Ilex minuta* CONWENTZ, × 4. 18. *Ilex prussica* CONWENTZ, × 3. 19. *Adenanthenum iteoides* CONWENTZ, × 5. 20. *Celastrinanthium Hauchecornei* CONWENTZ, × 6. 21. *Stephanostemon Helmi* CONWENTZ, × 4. 22, 23. *Mengea palaeogena* CONWENTZ, × 5. 24, 25, 26. *Clethra Berendtii* CASPARY, × 6. 27. *Billardierites longistylus* CASPARY, × 3.

call them late Eocene or early Oligocene so long as we know exactly where they come in the paleontological procession, since it is particularly difficult all over the world to go out in the field and say that at any one point the Eocene ended and the Oligocene began. We are using human concepts of time units for that which was itself continuous.

I can see no conclusive reasons for following Conwentz, Jentzsch and others who regard the amber flora and fauna as Eocene; von Linstow (1922), for example, considers the latter to be as old as lower or middle Eocene, but both the flora and fauna are very different from any we know of that age. The southern element may represent the surviving part of the late Eocene biota at a time when the region was being overwhelmed by northern invaders; or the amber may record two more or less distinct facies—a southern and earlier, and a northern and later; or the northern may have come from the great north land as shown on the accompanying map, which would have had a somewhat more severe climate; and the southern may have represented the surviving warm fauna and flora of its southern coasts.

As I picture the amber forests from the evidence of the plants my picture agrees fairly well with that which modern authorities derive from a study of the insects, namely, that we have a mixture of forms whose existing relatives still live or could live at the same latitude with others whose relatives now live in warmer climes. Certainly, the climate was temperate and not in any sense tropical. This is clearly indicated by the abundance and variety of coniferous trees, as well as by the northern element in the insect faunas; but among them we find representatives of a number of warm-temperate types, and I think we are justified in concluding that the climate was much more genial, and the floras and faunas much more extensive and varied than is the case in Samland at the present time.

THE PROGRESS OF SCIENCE

EDITED BY EDWIN E. SLOSSON
Director of Science Service

SCIENTIFIC AMATEURS

MANY workers in science now-a-days are business men, working in science as a hobby. Benjamin Franklin set the example for such scientific amateurs, for he was one of the first of them in America. A printer by trade, a diplomat by profession, Franklin was a scientist by avocation, and to read his autobiography, and to see some of his instruments which are still preserved in Philadelphia, one can hardly tell which side of his nature he was really most interested in. One has the suspicion, however, that he was chiefly interested in his science.

In England at the same time as Franklin there was another famous scientific amateur, using the word "amateur" in its best sense, a "lover" of science, not necessarily a novice. This was a clergyman, named Joseph Priestley, who made for himself a permanent place in the history of science by the discovery of oxygen. England has produced many scientific amateurs. Sir William Herschel, one of the greatest astronomers of all time, was originally a music teacher at Bath; and to-day, the secretary of the Royal Astronomical Society, and one of the leading astronomers of his country, is the Reverend T. E. R. Phillips, the active rector of a parish of the Church of England.

But the United States also has its scientific amateurs. Up in the hills of Vermont, in the town of Springfield, is a factory which makes machine tools. The president of the company gives the business his personal attention, and a few years ago was honored by his fellow citizens by being elected to serve a term as governor of his state. But James H. Hartness, for that is his name, has another side to his nature, like Benjamin Franklin. If you pay him a visit, he will probably show you around his works, and then take you to his home, on a hill above the town. At the back of his house there is a curious-looking structure, which at first glance bears some resemblance to a turret on a battleship, with a single gun sticking out from it. It is a turret, all right, but not a gun, for it is what Governor Hartness, who invented it, calls a "turret telescope."

With the usual form of telescope in an observatory dome, the inside of the building must be at the same temperature as the outside, otherwise the warm air from within will rise and go out through the slit in the dome towards which the telescope is pointed. This has the same effect as hot air rising from a stove and plays havoc with the distinctness of what the observer sees. But with the turret telescope, the instrument itself is mostly in the open air, outside the turret, and the image is brought inside by a reflecting prism. The inside of the turret may be kept as warm as desired as there is no opening for warm air to leave. To one who has gone through the rigors of a Vermont winter, this is a distinct advantage, and as a further convenience, Governor Hartness has an underground tunnel connecting the observatory with the cellar of his house.

There is a group of amateur astronomers, spread throughout the country, who perform scientific work of real value. This is the American Association of Variable Star Observers, which was

CHARLES DOOLITTLE WALCOTT

SECRETARY OF THE SMITHSONIAN INSTITUTION FOR TWENTY YEARS AND PREVIOUSLY DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY. DR. WALCOTT, WHO IS DISTINGUISHED FOR HIS CONTRIBUTIONS TO CAMBRIAN PALEONTOLOGY, HAS BEEN PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND OF THE NATIONAL ACADEMY OF SCIENCES. IN HIS DEATH, AT THE AGE OF SEVENTY-SEVEN YEARS, AMERICA LOSES ONE OF ITS MOST INFLUENTIAL SCIENTIFIC LEADERS.

established under the aegis of the Harvard College Observatory. With the building of the great telescopes in modern observatories, many people think that these instruments are essential to any observations of value. But while these telescopes have made possible the great advances in modern astronomy, there is still a large amount of work that can be done satisfactorily with smaller instruments. To use a great reflector for such a purpose would be about as sensible as to roll bread dough with a steam roller, for there is enough work to be done with the "Big Berthas" which only they can do, to keep them busy all the time.

A large class of stars are known as "variables." They change in brightness more or less periodically. Most of these are bright enough to be seen with a small telescope, but to check up on their variations a large number of observations, made fairly close together, are required. The American Association of Variable Star Observers, with its large number of small telescopes, watches these and its members report regularly to the Harvard Observatory. These amateur astronomers are drawn from all walks of life—one very active member, until his recent death, was a Pittsburgh locomotive engineer, who came in from his run about midnight, and then observed until daylight.

But astronomy is by no means the only science that has its amateur devotees. Take the instance of a prominent New York investment banker, who lives in one of the city's suburbs, Tuxedo Park. This man, Alfred L. Loomis, by name, has established at his home a private laboratory where he is experimenting himself, and aiding other scientists to experiment, on "long shots"—scientific problems that offer too little immediate return for the average university laboratory to investigate, but that may develop into something of importance.

Already, in cooperation with Professor Robert W. Wood, of the Johns Hopkins University, who is one of the world's leading experimental physicists, Mr. Loomis has investigated the super-sound waves that Professor Wood first observed during the war when he was working at the Toulon Arsenal in France. By passing a powerful oscillating electric current through a crystal of quartz, it is made to vibrate as fast as 200,000 times a second. The waves from this are similar to sound waves, except that they vibrate far too fast to be heard. The ear is not sensitive to vibrations faster than about 20,000 a second.

When the crystal is placed in the bottom of a vessel of oil, and its vibrations are passed upward into a glass of water, they produce strange effects. A fish placed in the water is killed almost instantly, microscopic plants are literally disintegrated, and when the curious investigator placed his finger in the water, a sharp pain, which extended to the very marrow of the bone, was experienced. Just what use this powerful new tool will be in science is still uncertain, for only the preliminary steps have been made in its investigation. It is where X-rays were a generation ago.

In an entirely different field of science, that of archeology, a hard-worked factory executive in Illinois has distinguished himself. George Langford, of Joliet, has taken up Indian mound excavating as many men take up golf. At that, he gets more exercise than most golfers, because what he has to do in his hobby is to work all day, when he has one to spare, with a pick and shovel like an ordinary laborer, with only one volunteer assistant to help him. But already his hobby has developed into a real pursuit of science, with important results, which has already won for him a place in the circles of his chosen science.

PRESIDENT COOLIDGE, MEMBERS, REGENTS AND ADVISERS OF THE SMITHSONIAN INSTITUTION

AT A MEETING IN WASHINGTON CALLED TO CONSIDER EXTENDING THE WORK OF THE INSTITUTION. THE MEETING HAD BEEN PLANNED BY DR. CHARLES D. WALCOTT, SECRETARY OF THE SMITHSONIAN INSTITUTION, WHO DIED THE DAY BEFORE THE SESSION STARTED, AND WHOSE LAST WISH WAS THAT THE MEETING BE NOT CURTAILED. LEFT TO RIGHT, FRONT ROW, SECRETARY OF THE TREASURY ANDREW W. MELLON; SECRETARY OF STATE FRANK KELLOGG; PRESIDENT COOLIDGE; CHIEF JUSTICE WILLIAM HOWARD TAFT, AND DR. C. G. ABBOT, ACTING SECRETARY OF THE SMITHSONIAN INSTITUTION. SECOND ROW, SENATOR JESSE H. METCALF, RHODE ISLAND; SECRETARY OF THE INTERIOR HUBERT WORK; SENATOR REED SMOOT, UTAH; SECRETARY OF AGRICULTURE WILLIAM M. JARDINE; SECRETARY OF COMMERCE HERBERT HOOVER, AND SECRETARY OF LABOR JAMES J. DAVIS.

His digging has been at the "Fisher mounds," near Joliet, and is important because he has unearthed three, and perhaps four, layers of remains of Indian civilizations that existed on the spot at various times in the past. In Old World archeology several layers of culture above each other are not unusual, but it is rare in America. Another important outcome of Mr. Langford's work is that for the first time a possible clue has been found to the earlier home of the Iroquoian Indian nation who played an important part in our colonial history. Previously, no remains of the Iroquois have been found west of Ohio, but in the second layer of the Fisher mounds pottery, ornaments and weapons suggestive of the workmanship of this race have come to light after remaining buried for many centuries. And under them are relics representing a still earlier group of Indians, about which little is yet known. Altogether, Mr. Langford has found hundreds of skeletons, as well as enormous quantities of the other relics.

STATIC AND THE WEATHER

TURNING now to the work of the professional scientists, in this case the radio engineers with the U. S. Navy, some work has just been announced on the relation of static and the weather. These troublesome noises are the result of electricity in the atmosphere. But static may prove to be of some use after all, for the Navy Department has found that it may be used to warn of such storms as the hurricane that struck Florida last September.

Beginning in March, 1924, the *U. S. S. Kittery* was used in a study of the value of weather maps in navigation. Before the experiments had been under way very long, it was noticed that there was a very definite relation between the state of the atmosphere, as recorded in the data for weather maps broadcast from the naval radio station at Arlington, and the static. Later, when the weather maps were broadcast and received by means of the machine invented by C. Francis Jenkins, where a duplicate of the transmitted map is automatically drawn on the ship, it was found that the receiver could be used to record static.

The Jenkins machine is used in connection with a radio compass. The latter device is equipped with a loop antenna so that signals may be recorded from one definite direction. As the loop is rotated, and peals of static in any direction are detected by the receiver, corresponding ink lines are drawn on the paper-covered revolving drum of the Jenkins machine. In the time that it takes the recording pen to travel from one end of the drum to the other, the loop is turned through a complete circle, so that the paper gives a graphic picture of the static in any direction from the observer.

The *Kittery* was fortunate enough, from the scientific viewpoint, to meet the Miami hurricane several days before it struck Florida, when the static was terrific in all directions. But as the storm proceeded, the static came definitely from its direction. Finally, there came a day with no static whatever and fine weather, but then as a new disturbance began to develop, static was again recorded from its direction.

Such hurricanes begin in the doldrums of the Atlantic Ocean, off Cape Verde, the western tip of Africa, several weeks before they hit the United States. The Miami hurricane, for example, began about September 5, though it did not reach Florida until the 18th. It is suggested that a group of radio compass stations, perhaps at San Juan, P. R., a point in the Barbadoes, and Trinidad, would be able to detect these storms as they approach. With three stations, where the lines from each cross would be the center of the storm, so that its position could be accurately plotted and sufficient time for warnings and preparation could be allowed.

DR. GEORGE D. ROSENGARTEN

DISTINGUISHED PHARMACEUTICAL CHEMIST OF PHILADELPHIA, WHO HAS BEEN ELECTED PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY BY A LETTER BALLOT OF THE 14,900 MEMBERS.

AMERICAN DIAMONDS

THOUGH little systematized search has been made, the complete total of diamonds found in widely scattered parts of the United States, if it could be checked up, would amaze the public that has long associated the queen of gems with the far places of the earth like Africa, Brazil and India. California, the Piedmont region of the Atlantic seaboard, and the region around the Great Lakes have all contributed some, but Arkansas is the only place in North America where diamonds are really mined.

Experts put the total Arkansas output at over ten thousand stones since diamonds were first found in Murphreesboro, in Pike County, in 1906. Most of them are being held by mining companies, but a few have been sold and the best and most complete collection of them out of the hands of the mine owners is in the U. S. National Museum. The finest of this lot have just come to the Smithsonian Institution along with the quarts of quartz, pounds of topaz and ounces of opal, contained in the famous collection of precious stones of the late Colonel Washington A. Roebling. The largest native diamond in the museum, according to Dr. W. F. Foshag, who is working on the collection, weighs slightly under 18 carats and is one of the prize Arkansas specimens. The best of them all, however, came to light in 1924, tipping the jeweler's scales at 40.23 carats and is the largest diamond ever found on this continent.

The diamond deposits of the world are of two types. Those in Brazil, India and Australia, and some of those in Africa, are placers where the stones have been concentrated by wind and water. The occurrence of isolated diamonds in gold placers in this country is accounted for by the fact that the gold nuggets and diamond crystals are heavier than the other particles of sediment and gravel washed down from higher levels and are consequently fairly commonly deposited in the same locality. The second type of diamond deposit is in solid rock of volcanic origin or in the soft earth or clay overlying it. Like this is the Arkansas diamond region, as well as the world-famous mines of South Africa.

Several diamonds have been found and equally many have undoubtedly been lost in gold placers in California. They are thought to be originally derived from the same type of diamond-bearing rock that has been washed down in broken bits in streams from the mountains of volcanic origin. Most of them are small and there is no telling how many more of the white glassy crystals have been thrown out of the rockers and washing pans of miners interested only in the gleam of yellow dirt.

In the Piedmont region of the Atlantic coast there have been a few found. Virginia claims a single isolated diamond, a big one around 23 carats having been dug up by a laborer working on a street excavation in Manchester as long ago as 1855. In Dysartville, N. C., a shiny pebble later found to weigh four and two thirds carats attracted the attention of a little boy sent to a spring for water. He fished it out and carried it home where it excited sufficient interest on the part of the grown-ups to send it to New York for examination. It proved to be the real stuff and a model of it was displayed in the Paris Exposition of 1889. It is now in the Tiffany Morgan Collection in the American Museum of Natural History. Several others have been found in the mountainous parts of the state mostly associated with gold placers.

Several stones of considerable size have been found in the Great Lakes section. One weighing 15 carats was turned up in Wisconsin while a well was being dug. It was given to a woman who was a tenant on the property who sold it for a dollar, but litigation ensued when the real value of the stone came out.

THE TWO RECORDING INSTRUMENTS

ON THE LEFT, THE STANDARD MOTION PICTURE CAMERA WITH SYNCHRONOUS MOTOR DRIVE; ON THE RIGHT, THE SOUND RECORDER.

A SECTION OF THE COMBINATION SOUND AND PICTURE FILM

THE MULTITUDE OF HORIZONTAL LINES ON THE LEFT MARGIN CONTROL THE SOUND REPRODUCER.

TALKING MOTION PICTURES

TALKING motion pictures in which the simultaneous timing of action and sound is assured have been announced and demonstrated by the Research Laboratories of the General Electric Company. The process means but slight change in standard motion picture projectors, since it involves only the addition of a sound-reproducing attachment and a loud speaker suitable for auditorium use. Both the picture and the sound are recorded on the same film.

One of the demonstrations has been with music to accompany feature films, the music being by a full concert orchestra. Development of this field requires no change in the technique of making the original film. After the original picture film has been made and titled, the accompanying music is played by a concert orchestra and is recorded on a film. The picture and sound records are then

printed on one film in the proper time relation.

To the casual observer the talking film does not differ from the usual motion picture positive. It is of standard width, but along the left margin there is a strip a small fraction of an inch wide on which is a series of horizontal light and dark bands and lines, of varying widths and intensities. It is this series of bands and lines which produces the sound. The film is passed through the reproducer at constant speed, and, as these light and dark bands pass rapidly before a tiny slit in an optical system, the amount of light is varied. The ever-changing amount of light is received by a photo-electric cell—the electric eye—which is extremely sensitive to any change in the amount of light striking it. The more light received, the more current it will permit to pass through its circuit. This current is amplified and changed from electrical to audible energy by an amplifier and speaker.

At this early date it is not possible to define the fields in which this new type of talking motion pictures will be of use. One of the first, however, will be in supplying a full orchestral accompaniment for pictures. The community picture house, accustomed to having a piano, or piano and violin, will be able to have the same music as the metropolitan theater.

COMBINATION SOUND AND PICTURE PROJECTOR

A STANDARD PROJECTOR IS USED, THE SOUND-REPRODUCING ELEMENT BEING MOUNTED DIRECTLY BELOW THE UPPER DRUM WHICH HOLDS THE FILM.

Another field is offered by the news reels. Not only will it be possible to show important persons, but they can talk to the audience, and visiting notables can extend their greetings.

Educationally, there are also many ways in which the new apparatus will be of service. Many schools and colleges are already equipped with motion picture projectors as an aid in class-room work, and the new film will be found of even more assistance. In the case of professors from abroad, it will be possible to record their lectures and demonstrations simultaneously, and to give their lectures the widest possible use by circulation of the film to colleges and universities throughout the country. Similarly, it will be possible to have an authority on the subject give a description to accompany any educational film for use in schools, the speech pointing out the important features of the picture simultaneously with their appearance on the screen.

Outstanding among the features of the new apparatus are that both the picture and sound records are on the same standard motion picture film, and that a standard motion picture projector, with an attachment for the sound reproducer, is used. Since the picture and sound records are printed side by side on the film, it necessarily follows that the two must be properly timed or synchronized at all times—it is not possible for the picture to break and the sound to continue, or for the sound to stop and the picture to continue.

There are three principal elements in the apparatus, including a standard motion picture camera, a sound recorder and a standard motion picture projector with a sound-reproducing attachment, all driven by synchronous motors. The pictures themselves are made in the usual way on standard film.

In recording the sounds, a microphone or sound collector of any desired type is employed, together with amplifiers. The microphonic system actuates a tiny vibrating mirror which records the sound on the film as light and dark bands, the light from a small incandescent lamp being reflected by the mirror through a tiny slit in the optical system in front of the film. The higher the pitch of note, the higher its frequency—and the greater the frequency of vibrations of the mirror which faithfully reproduces each sound vibration as a mark on the film.

The sound-reproducing attachment which is connected to the standard motion picture projector consists of a photoelectric cell behind the film and a small electric lamp with suitable optical arrangement in front of the film. As the film passes a small slit, similar to the one used in making the sound record, a varying amount of light is admitted to the photoelectric cell, the amount of light depending on the photographic density on the sound track. The result is that a very minute and varying current, an exact replica of the sound wave, is produced. This tiny current is amplified and led to a loud speaker which reproduces the sound in sufficient volume to fill the auditorium.